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ELECTROMECHANICAL components & systems DESIGN

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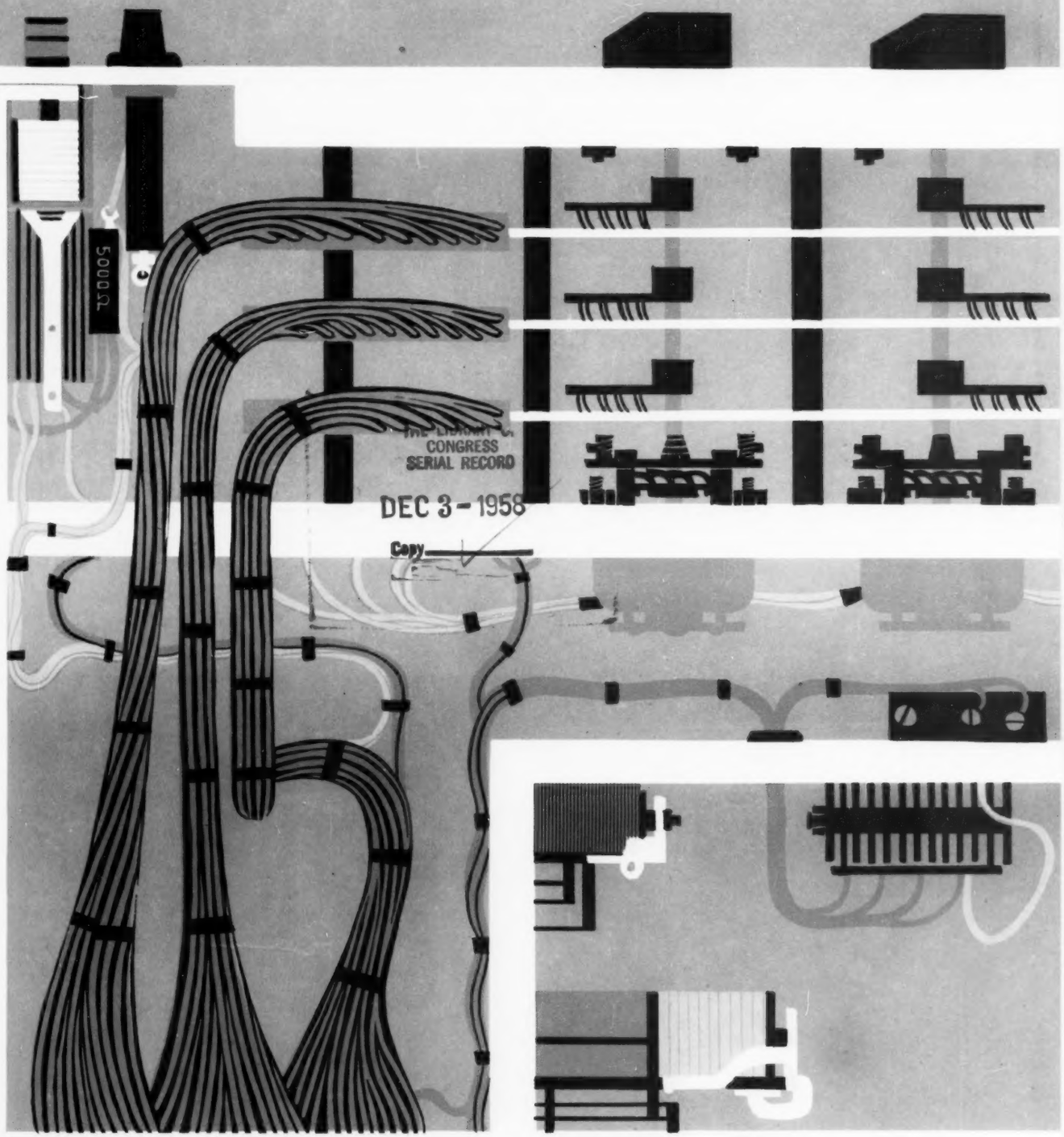

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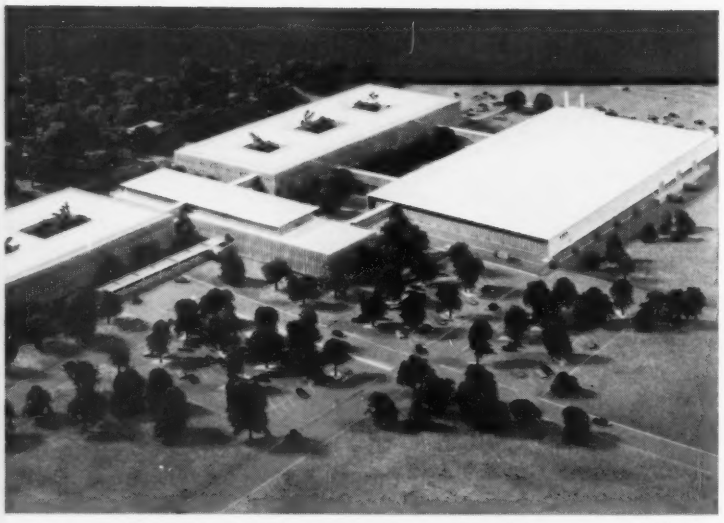

Pictured above is our new Research and Development Center now under construction in Wilmington, Massachusetts. Scheduled for completion this year, the ultramodern laboratory will house the scientific and technical staff of the Avco Research and Advanced Development Division.

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IDEALS AND PRACTICALITY

"Science and Philosophy mutually criticize each other and provid imaginative material for each other."... Alfred North Whitehead

In the increasing preoccupation of science with material things and progress, the truth of this statement by one of our greatest philosophers is often overlooked and forgotten. The scientific philosopher is a rare being and is becoming rarer still, nor can he be adequately replaced by the group technique or the 'brainstorm' session.

It should be one of the noblest aspirations of all our sciences to provide for the true contemplation of the inner meaning of facts and to stimulate that interplay of mind on mind by which alone we may progress.

In all these things, however, we cannot forget the problems peculiar to research and development in private industry. The obligation to work to otherwise-determined time-scales poses a nice problem in balancing ideals against the practicalities of everyday life.

It is in this field that the test of management comes. Its success at meeting such continuously conflicting requirements determines the character and ultimate success of the organization.

With such thoughts as these in mind, we here at Research and Advanced Development Division of AVCO are seeking unique people. We wish to foster the creative minds and fundamental thinkers, while preserving an atmosphere of self-discipline free from a rigid hierarchy of command and organization.

Dennis W. Holdsworth

Manager, Computer and Electronic Systems Department

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4

ELECTROMECHANICAL

components & systems | DESIGN

CONTENTS

COMPONENTS DESIGN

SYSTEMS OF COMPONENTS

NEW TECHNIQUES

NEW MATERIALS

DESIGN TIME SAVER

RESEARCH

MANAGEMENT

ADVERTISING INDEX

8 DIGITAL CLOCK
Rotary solenoids and printed circuit commutators produce time patterns for many applications

12 TELEMETRY
Precision voltage monitor for accurate data transmission

16 BALL BUSHING
Low friction linear instrument bearing

24 A SMALL OPTICAL TRACKER
Three circuit techniques for radiation tracking

30 INSTRUMENTATION
Clamp-type A-C microammeter, transistorized

32 FREQUENCY DIVERSITY RADAR
Improved radar displays

34 SCAN CONVERSION EQUIPMENT
TV presentation of radar information

35 AIRCRAFT INSTRUMENT
Two-gyro master reference

36 GEAR TRAIN ANALYZER
Constant torque actuator measures lost motion

38 DYNAMIC TESTING TIMESAVER
Filming a failure with X-ray

45 DUCTILE BISMUTH
New process eases applications

49 THIN DIELECTRIC SEMI-CONDUCTOR LAYERS
Translation of U.S.S.R. Technical Report

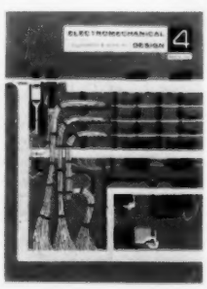
50 RELIABILITY TESTING
A specific technique for determining if your equipment is adequately engineered

56 COMPREHENSIVE APPROACH TO RESEARCH EVALUATION
Judging past performance for the purpose of guiding future action

60 DO ENGINEERS ENCOURAGE A GOOD COMPANY CLIMATE?
The hen and egg problem

62 PRE-TESTING PRODUCT DESIGNS
Answers to tough questions

64



This month's front cover by our art director, James Flora, illustrates the digital clock described in the article on page 8.

—CIRCLE 1 ON INQUIRY CARD

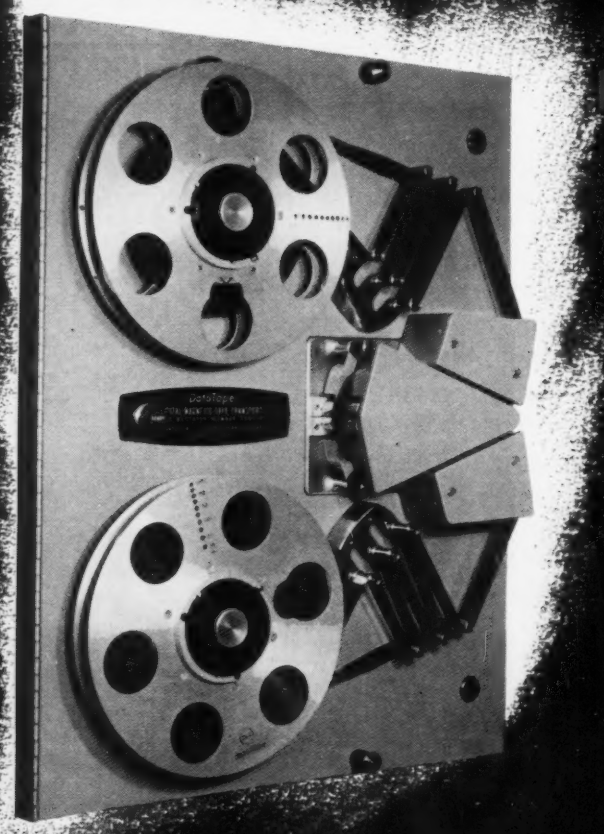
STAFF COLUMNISTS

5 Andrew R. MacAndrew • FUTURE ENGINEERS
Production line or custom made?

20 Emile Labin • EDDY CURRENT DEVICES
Report from France

41 David Bandel • TRACING AND CHASING WITH RADIOISOTOPES
Materials progress report

63 Martin E. Kagan • CONVENTION NOTES
Ideas for your design file



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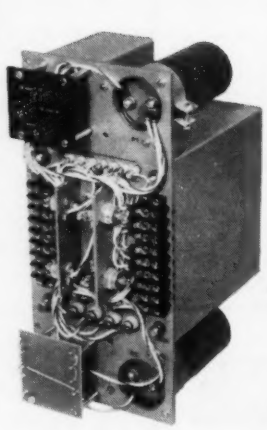

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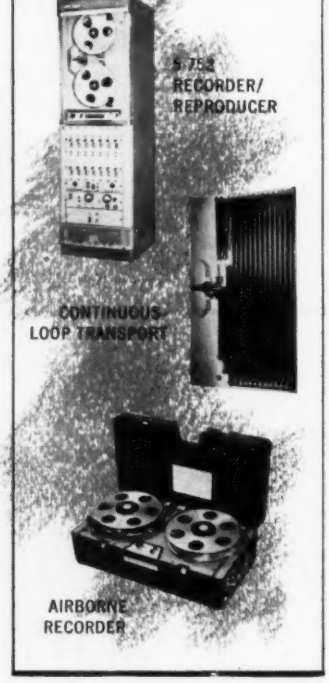

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INVESTMENT BARGAINS

On page 5 in this issue, our Foreign Editor, Andrew MacAndrew, compares American and foreign school curriculums, indicating that American standards of technical training not only lag those of Russia but are even further behind those of most European countries.

These facts, like the Sputniks, are not easily explained away. Do we need more evidence that our scientific and technological status is diminishing in spite of our awesome progress? Don't we now have sufficient reason to resurvey the institutions that support our technology?

A cursory glance reveals two areas in need of immediate attention; areas which, to a great extent, have been left to the incentives of the "market place": Education is being degraded by the level of teachers' salaries, and basic research, by being tied to profits.

Widespread indifference to teachers' salaries indicates less than deep concern for academic standards or the quality of our students and certainly diminishes our rate of achievement.

Comparatively little of our research and development dollar is spent on basic research, the stock pile from which industrial research and development draws its needs. With the exception of a few industrial giants, most companies still gear their research efforts directly to profits. On this basis the average company that develops new equipment must, of necessity, amortize its investment before it can afford further developments that would make the earlier ones obsolete. Gearing research directly to profits may be an economic necessity, except when it endangers our technological status.

Over the past year various authorities who visited Russia reported that without question the Soviet Union is providing up-to-date laboratories and the most modern experimental equipment for its budding scientists and engineers. They say it attracts persons of the highest intellectual caliber into these educational programs and research organizations, and increasingly recognizes that scientific freedom is important in achievement of scientific and engineering goals. There appears to be no question but that there has been a change in the scientific climate and potential of the Soviet Union even though their political freedom is still non-existent.

Unquestionably, the Soviets recognize the price they have to pay to achieve these goals, and they recognize it as an investment bargain.

When are *we* going to buy?

Robert B. Brotherston

EDITOR

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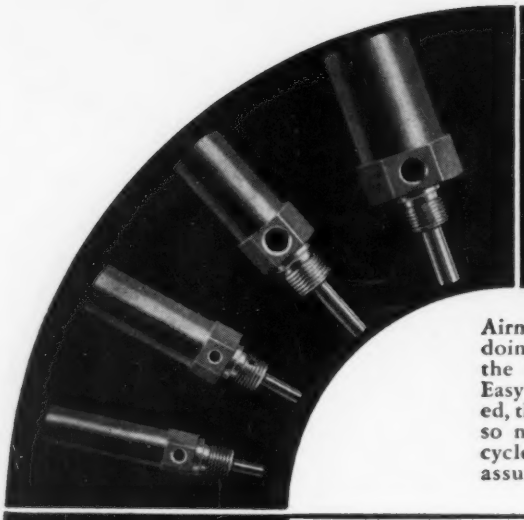

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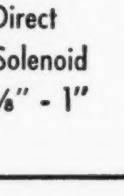

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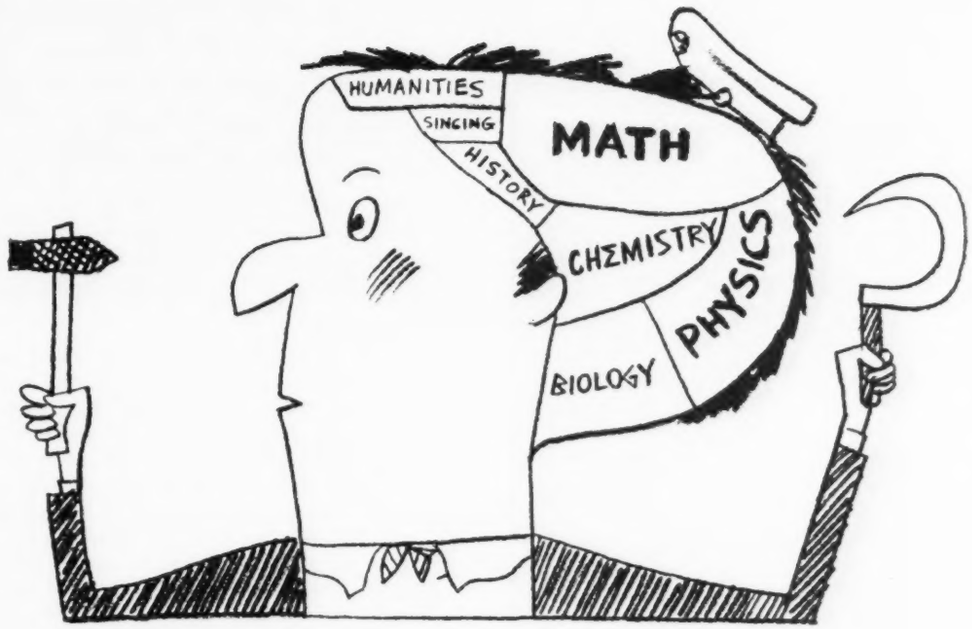
Andrew R. MacAndrew
Foreign Editor



FUTURE ENGINEERS: PRODUCTION LINE OR CUSTOM MADE?

The Soviet educational system was discovered a couple of years ago by some American travelers. These scouts brought home a picture that has become deeply ingrained in the minds of their compatriots: attentive, disciplined school children being fed staggering doses of math, physics and chemistry by teachers wallowing in social prestige, with a background sound effect supplied by the rustling pages of technical books turned by the calloused hands of workers who spurn their beds for libraries open day and night.

And now that the sputniks have been heaved into their orbits by the mighty Soviet-made ICBMs, and the US Office of Education has published some awesome statistics on the Soviet pedagogical effort (so awesome in fact that it felt obliged, according to the original researcher, to sandwich them between appropriate comments), a furor of argument has arisen. On the one side are those who would summon Americans to wake up and lick the Russians at their own diabolical game of learning even if this means relinquishing cherished freedoms such as that of ignorance. On the other side are those who feel that a free democracy should never imitate the state-controlled, totalitarian, materialistic education of the Soviet; that, in the long run, somehow, America will prevail.

Both these approaches are based on an impressive array of statistics. But, in fact, when these figures are brought in to prove either the "materialism" of the Soviet approach or the deadly efficiency of their training of scientists and technicians, they are about as helpful as figures for the velocities of wind and current would be in finding out what cargo a ship is carrying or whether the skipper beats his wife. We know, for instance, that in the course of his ten years in the secondary school a Russian student has a total of 9857 hours of instruction of which 2788 are spent on Russian language and literature, 1980 on math, 660 on history, 544 on physics, 660 on physical training, 33 on singing, 660 on foreign languages, and so on. We also know that Moscow announced in 1955, "more and more time will be devoted to teaching physics, chemistry and biology by reducing humanities to secondary importance," and that, as a result, today, the sciences get 53 percent of the student's time and the humanities, 47 percent. But this tells us practically nothing about the cultural platform to which a Soviet ten-year school brings a student or how well equiped he is to become a good engineer, scientist or technician, and it doesn't even touch on the matter of totalitarianism in their educational system.

Some measure of answer to these questions can be found in the detailed instructions for 1957/58 sent out to teachers by the Russian Republic Ministry of Education. The teacher is told how much ground to cover in what time and what should be taught when. Thus, the math teacher is reminded that his pupils will need a particular point in geometry by the time they start on certain aspects of optics in their physics course. And similarly the physicist is reminded to think of the chemist and the chemist to keep the biologist in mind.

Now all this cannot be called an attack on freedom. The fact that it is left to a central body of educators to work out a well-balanced and coordinated program, such as should constitute a prescribed minimum for every member of a modern society, is no evidence of tyrannical interference. It is nothing but an extension of compulsory literacy. Nor is it a peculiarly Soviet characteristic. As a matter of fact, a prescribed curriculum existed in tsarist Russia before it was swept over by the revolutionary wave and it is largely this system which the Soviets later rebuilt. And such a system also still exists in almost all NATO countries outside the USA.

However, another impression emerges after reading the full set of ministerial instruction to the teachers of all subjects. Despite the anesthetizing dullness of Soviet pedagogical jargon, one soon becomes aware that the tone is not always the same, that in some subjects it is more emotional than in others and that, as this emotion grows, the "political message" becomes more and more obvious.

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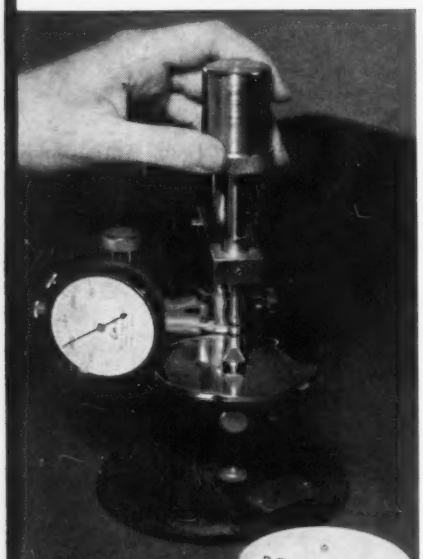

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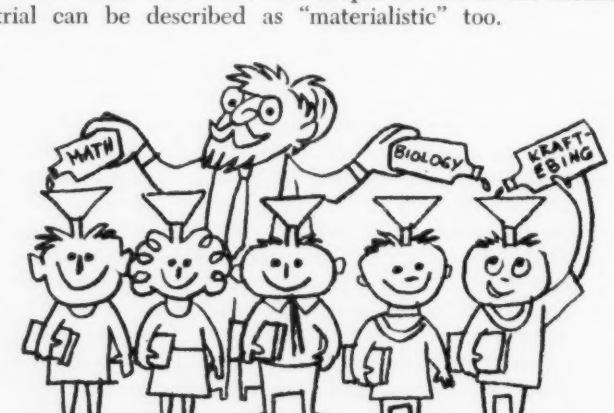
cal message" becomes more and more obvious.

In a spectrum of emotional intensity, one finds math at one end and history at the other. The math teacher is merely reminded that his "problems should have a proper background of socialist construction," and the physics and chemistry teachers are given similar advice with an additional injunction to "emphasize the achievements of our national genius." But as soon as the subject begins to touch upon living matter, things are liable to go haywire, and the biology teacher's guide (in which Lysenko makes a modest reappearance) is already an irate diatribe against certain Western theories of genetics. As to the tail end of the spectrum, Russian literature and history, their case is too well known to dwell upon.

This situation is curiously reflected in the flow of letters to the editors of the *Uchitelskaya Gazeta* (the paper of the Soviet educators) complaining that while the math, physics and chemistry textbooks are out-of-date, being up to twenty years years old, the textbooks of biology, literature and all the other subjects are well-nigh never available because almost as soon as a new edition arrives, it is again snatched out of the children's hands to be revised once more.

Now, there is no doubt that this last aspect of the Soviet educational concept does reflect totalitarianism and does interfere with the freedom of the teacher and of the student. And, of course, it interferes with the free investigation of facts, with the experimental method in general, tending to suppress results when they clash with dogma. But whether this can be described as "materialism" is another matter. Unless the anti-Scopes faction in the monkey trial can be described as "materialistic" too.



From statistics we know that an estimated 87.5 percent of students entering the first grade in the USSR drop out before reaching the tenth grade. From the clamor for middle flight technicians echoed by the Soviet press, we may deduce that many of these people leave school even before reaching a general level of knowledge after which they could become effectively specialized. As to the 12.5 percent of students who do go through and graduate, it may be interesting to take a look at the state-controlled exams which assess their academic abilities.

Last summer a Soviet candidate had three written tests. The Russian test, which he had to pass to qualify for the next, was a composition on a literary subject which he could flunk because of bad spelling, poor grammar or an undeft application of the "socialist-realistic" critical approach. If he avoided all these pitfalls, he had to take two more written tests, geometry and trigonometry, before reaching his orals. In both fields he had to demonstrate a theorem, establish a formula and solve a problem. In geometry he had studied as far as polyhedrons and the solids of revolution, in trig, oblique-angled triangles and inverse trigonometric functions. If he passed these hurdles, in his

orals he had again to answer questions on Russian literature and others in algebra, physics and chemistry.

Certainly, since we are told that only one US high school student in seven elects to continue with his mathematics, one in four has one year of physics, and so on, an average American high school graduate trying to cope with the Soviet tests would be helpless. But a French boy of the same age who had prepared for his *bachot* in a *lycée* (no tuition fees for over 20 years) would have been quite agreeably surprised if his math test were on the Soviet level. In fact, he would have studied a whole intense year beyond polyhedrons and other items acquired in the Soviet tenth grade and, besides, he would also have a written test in physics, and in two languages (ancient or modern), and a French dissertation that, like the Russian, would eliminate him if he was unable to spell. And, to boot, he would have to take orals in all these subjects as well as in biology, geography, and history. On this last, Russian students were not examined at all last year.

Of course, it is true that if the French candidate had to apply socialist-realist criticism to Victor Hugo the way his Soviet counterpart applies it to Pushkin, he would be eliminated then and there.

Thus, it would appear, the Soviet educational system is not quite the streamlined production line supplying technicians, engineers and scientists to a faceless state. In reality its academic standards of science teaching (53 percent of the curriculum) are rather inferior to those in most Western democracies since these do not have to cope with handicaps such as the barring until 1952 of Einstein's theories as "bourgeois and idealistic," and the diffidence with which, even to this day, quantum mechanics is treated because of its principle of uncertainty which refuses to fit into the comfortable pattern of dialectical materialism.

As to their humanities, to which the Soviets used to devote 60 percent of their school hours and today devote only 47 percent, there is nothing much to worry about. It is hard to understand what difference it would make to the world at large if a Soviet boy were to spend more or less hours applying historical materialism to the trial of Joan of Arc or analyzing the literary value of Lincoln's speeches in the light of "socialist realism," the compulsory literary theory.

Finally, after all has been said, we may also question the degree to which the success of any school system is really reflected by technological achievements. Not so long ago, the USA had both nuclear bombs and a considerable advance in the means of their delivery, while her school system was just about what it is today.

A much more obvious Soviet strong point is to be found in their chains of research institutes, which are lofty platforms beyond the reach of stifling dogma and better coordination in the dissemination of world-wide technical data.

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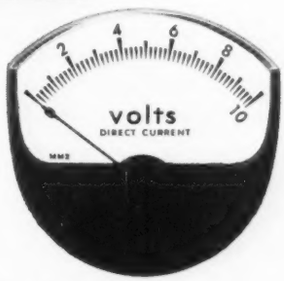

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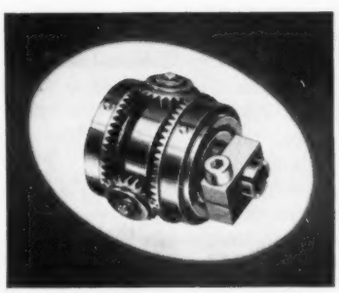

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DIGITAL CLOCK

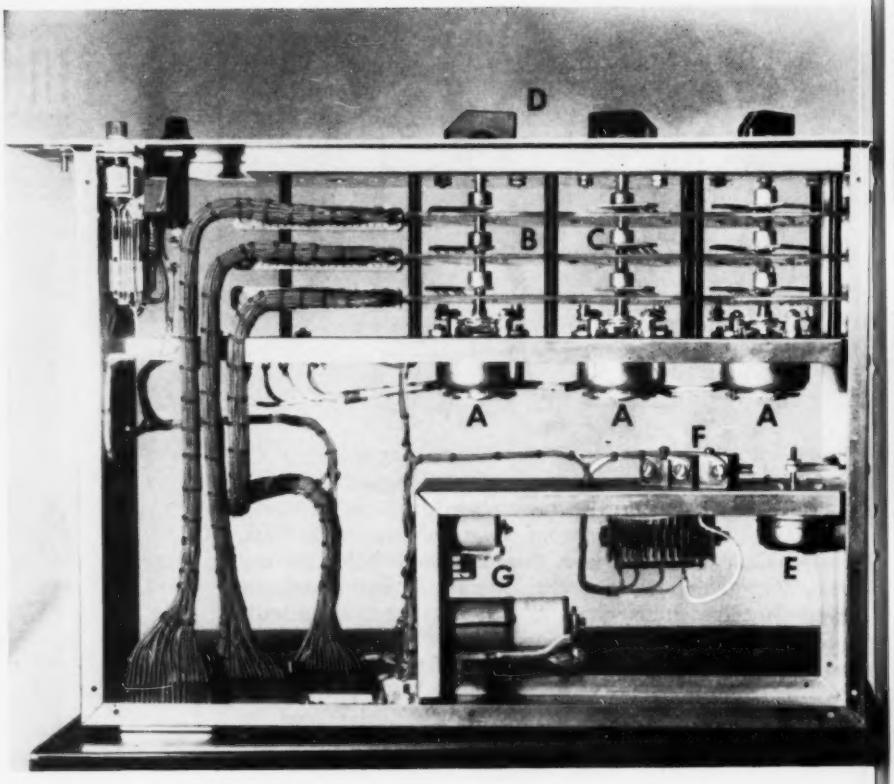
Solenoids Rotating Brushes Around Printed-Circuit Commutators Produce Patterns Representing Time

Increased use of digital equipment in all phases of science, business and industry has brought about the need for a device that can produce a digital representation of time, suitable for feeding a wide variety of data loggers, digital printers, telemetering systems and computers. Such a device is the Digital Clock produced by the Chronolog Corporation, Philadelphia, Pa.

DESIGN OBJECTIVES

The functional specifications that guided the design of this electromechanical clock were defined for us by Martin Resnick, President of the corporation:

- The clock was to produce a parallel, decimal contact closure pattern representing time in hours and minutes. Provision for expansion of the design to produce outputs of time to the nearest tenth of a minute or nearest second was to be included.
- An externally wired common lead was to be provided for each digit position to permit the clock to actuate both parallel and serial readout devices.
- Up to three electrically independent outputs were to be available in one unit so that a single clock could actuate a serial readout, such as a typewriter; a parallel readout, such as a tape printer; and also program system functions on a time basis so as to initiate log cycles, start computational cycles, and start and stop process equipment.
- During periods of time change, no incorrect, or so-called "ambiguous" readings were to occur. For example, during the instant of time change from 09:59 to 10:00, all four digits in the output must change. If the hours digits were to change before the minutes digits, there would be a brief interval during which the output would be 10:59. This type of ambiguity was to be avoided.
- The time was to be easily set by means of manual setting adjustments. An indication of time was also to be provided.
- The unit was to mount in a standard 19-inch relay rack and was to require only 3½ inches of panel height.
- Cost was to be kept to a minimum so that the unit could serve as an economical system component.
- Reliability and maintainability were to be high. It was felt that one to two years of continuous, maintenance-free operation should be possible. All components were to be readily accessible for checking and servicing when required.

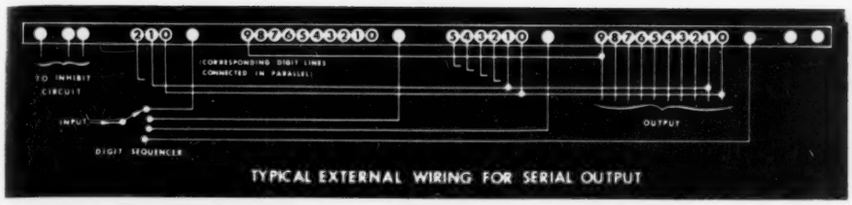


Internal construction of the Chronolog Digital Clock with three outputs installed. The rotary solenoids are shown at A. B indicates the printed circuit boards. The brush-holders, C, are mounted on the rotary solenoid shafts. Knobs, D, on the ends of the shafts permit time adjustment and indicate the time. Operation of the clock is extremely simple. A synchronous motor, E, rotates a cam which trips a micro-switch, F, once per minute. When the microswitch trips, the units-minutes rotary solenoid steps to the next position. A simple feedback circuit on the printed-circuit output board steps the tens of minutes rotary solenoid whenever the units-minutes shaft is resting in the nine position; for instance, at 10:49, the next time change produces an output of 10:50. Similarly, when the units-minutes solenoid is at nine and the tens-of-minutes solenoid is at five, the hours rotary solenoid is stepped on the next time change, for example, at 10:59, the next time change produces an output of 11:00. The rotary solenoids require about 50 milliseconds to step forward. During this 50 milliseconds, an ambiguous reading is possible. To prevent it, relays are used to open the load switching contact for 100 milliseconds after the micro-switch is tripped. In this way, either the output voltage can be interrupted for 100 milliseconds at time change or the readout trigger circuit can be disabled for this period to prevent readout of ambiguous values. The relays are shown at G. The load switching contact, supplied with each output, can also be used to increase the current carrying capacity of the output. Although the printed circuit boards and the brushes can carry appreciable currents, they should not switch more than 100 milliamps. Using load switching contact relays to open-circuit the output power before the solenoids move the brushes switches the current at the relay contacts rather than at the printed circuit board. The relay contacts can carry the equivalent of 0.5 amps for each of the four digits of the output at 110 volts direct current, non-inductive.

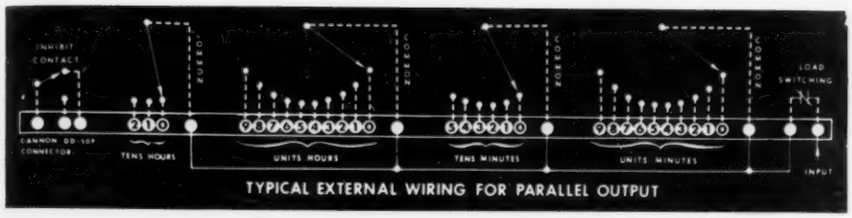
CHRONOLOGY OF THE DESIGN

Because the basic cycle of the Digital Clock was to be one minute, it was felt that electronic approaches to the design, inherently capable of much higher speeds, would be overly expensive and complex. The ideal answer to the design problem seemed to be an electromechanical approach.

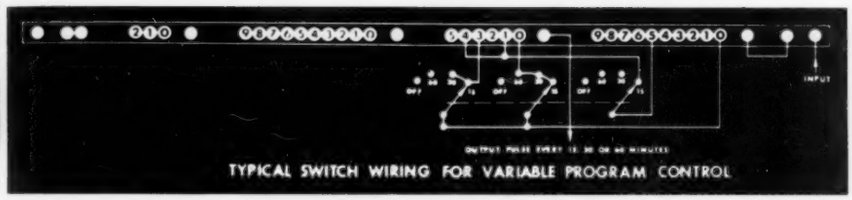
The initial design was based on use of telephone-type stepping switches, wired to produce proper output patterns in each position. Preliminary designs indicated that the cost would be too high due to the amount of wiring involved. Problems of manual time setting and time indication would further increase the cost since setting switches and a visual display were to be added to the unit. In addition, the space limitations were somewhat ex-



TYPICAL EXTERNAL WIRING FOR SERIAL OUTPUT



TYPICAL EXTERNAL WIRING FOR PARALLEL OUTPUT



TYPICAL SWITCH WIRING FOR VARIABLE PROGRAM CONTROL

Typical wiring diagrams for various outputs. The inhibit contact is used to signal that a time change is going to occur one second after the inhibit contact changes. This feature is used to delay serial readouts such as typewriters, which cannot complete their readout before the time change occurs, thus preventing ambiguous readings due to time change occurring in the middle of a serial printout.

treme for this type of design.

"To avoid wiring costs," Mr. Resnick said, "we decided to design around printed circuit wiring techniques. Most of the wiring cost in the Digital Clock is due to the point-to-point wiring of the output leads." Units-minutes requires ten wires plus a common (0 to 9); tens-of-hours requires three leads plus a common (0 to 2). Thus, a total of 33 wires per output is needed; three outputs would require 99 wires.

Using printed circuit commutators instead of wired switches provided not only the commutator segments but also the necessary wiring between segments. The only additional mechanism needed was a device to drive brushes around the printed circuit commutators to connect the proper segments and produce the digital contact pattern output.

Original designs were based upon the use of a gear train with three output shafts, rotating respectively at 1/10 RPM (units minutes), one RPH (tens of minutes) and one RPD (hours). Brushes on each output shaft were driven around the appropriate printed circuit commutators to produce the outputs.

This design was rejected because of the following disadvantages:

- It was difficult to fit the gear train into the 3½ inch panel height
- Elimination of ambiguities at transition points was overly complex, due to the slow-moving brushes
- Manual setting of the gear train was difficult, requiring either too much force or excessive turning
- Over-all cost was too high.

From this design experience, however, the designers realized the advantages of printed circuit commutators. To add outputs to such commutators, the only equipment required was printed circuit boards and brushes. Space requirements for the printed circuit commutators themselves were small. Wiring was relatively simple and could be done outside the unit in the form of pre-wired cable assemblies.

Efforts were then directed toward finding a simpler, more compact method for rotating the brushes around the printed circuit commutators. Use of rotary solenoids was considered and found to be satisfactory. Tests showed that power requirements were well within the capabilities of such devices.

The requirements of the design were for a rotary solenoid that would make one complete revolution in ten steps (units minutes), another that would make one complete revolution in twenty-four steps (hours). The minutes were split into separate commutators for units and tens because the tolerances on the printed circuit became too critical when a small circle was divided into sixty segments.

The ten-step and the twenty-four step rotary solenoids were commercially available. However, a six step unit was not. Therefore, the designers chose a twelve-step unit and designed the printed circuit commutator with twelve segments, opposite segments being connected in parallel electrically; thus, one twelve-step revolution of the tens-of-minutes solenoid is equivalent to two hours, with the digits 0 to 5 repeated twice.

The resultant design fitted easily into the required 3½ inch panel height; the actual housing was only 3 inches high. Bringing the shafts of the rotary solenoids through the front panel made it possible both to indicate the time and permit easy manual setting of the time with no added equipment. According to Mr. Resnick, one rotary solenoid can easily drive three sets of brushes so that three outputs can be provided in one clock with no additional equipment. Details of the clock design are described in the accompanying illustrations.

CONSERVATIVE DESIGN

"Chrono-log's designers are firmly convinced that reliability is primarily the result of conservative design," Mr. Resnick said. "In this respect, the Digital Clock is an excellent example. Accelerated life tests have been run equivalent to two years of full-load, continuous, maintenance-free operation. At the conclusion of these tests, the units were still operating perfectly with no significant wear or decrease in performance."

Mr. Resnick cited several examples of the conservative approach employed:

- The rotary solenoids are designed for a duty cycle of 25 percent. In the worst case, that of the units-minutes, the solenoid operates only one second out of every sixty, a duty cycle of less than 2 percent. In addition, these rotary solenoids are capable of operating at speeds of about ten steps per second. The units-minutes solenoid, again the worst case, operates only once per minute.
- The printed-circuit boards are plated with rhodium, with sufficient thickness to permit up to 50,000,000 brush revolutions at speeds up to 500 rpm. Actual service conditions are trivial in comparison, since the units-minutes brushes make only about 50,000 revolutions per year.
- The rectifier that supplies direct current to the rotary solenoids and relays is operated on less than a 2

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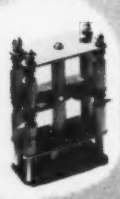
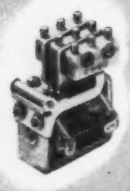


High Voltage Switching Relay, Model RL-906, for Radar, Sonar and Missiles applications.
Size: 3 5/16" x 4 15/16" x 1 3/8"

High Voltage Switching Relay, Model RL-904, Bu-ships rated Discharge Switch.
Size: 4 15/16" x 6 15/16" x 4 11/32"



D-C Miniature Relay Model RL-503ES, 5% Differential between Pull-in and Drop-out, Open or Hermetically sealed.
Size: 1 3/8" x 1 1/2" x 1 5/8"

D-C Miniature Solenoid, Model SO-151, High magnetic efficiency for improved power-to-size ratio.
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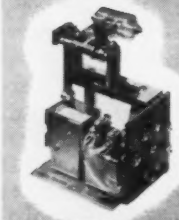

Vacuum Switch Relay Model RL-1011, for High Voltage applications up to 10KV at 5 amps. (live switching)
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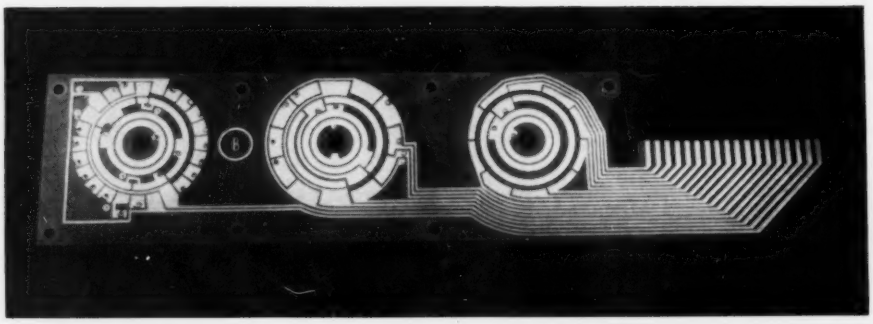

Front of one of the printed circuit output boards, with three commutator rings for units-minutes, tens-of-minutes and hours. Normally, time is shown on the basis of 24-hour time, that is, 2:45 PM is printed as 14:45. However, in some cases, 12-hour time is desirable, such as for display of time to the operator. The basic 24-hour output can be easily converted in the field to a 12-hour output. The hours commutator ring, at the left of the printed-circuit board, has small numbers indicating specific conductors in the circuitry. Cutting these conductors with a razor blade so as to break the electrical continuity converts the output from 24 hours to 12 hours. There are several conductors on the rear of the board that would also require cutting in this manner. The only other change required is to add four brushes to the hours brush-holder.

percent duty cycle.

• The accelerated life tests actually imposed 30 to 60 times the normal duty cycles on such components as the solenoids and rectifiers, but no failures occurred.

Maintainability of the clock is high, according to Mr. Resnick. "Within the normal life of the unit," he said, "it is doubtful whether more than routine cleaning will be required." All components are readily accessible by removing the top and bottom covers. Wiring is color-coded and complete wiring diagrams and operating instructions are furnished.

The basic design can be expanded to obtain higher time resolutions by addition of a rotary stepper switch and cam timer mounted in a bracket substituted for the relay and micro-switch bracket in the basic model. The manufacturer claims that with the rotary stepper the unit can supply an ultra-reliable output with a time resolution of tenths of a minute or seconds.

APPLICATIONS

The Digital Clock has many applications. It is used to furnish time data to computing systems. It also identifies the time readings on digital log sheets produced by data loggers operating in refineries, engine test stands, chemical plants, laboratories and pilot plants. It can feed tape punches, typewriters, magnetic tape units, tape printers, digital displays and all other digital readout devices, both serial and parallel. In addition, it provides, in the basic minutes-output design, 1440 different contact closures per day which can be used to program the operation of process equipment or digital readout systems. The high current capacity of the outputs when used with the load switching circuit permits programming process equipment in many cases without the use of intermediate relays.

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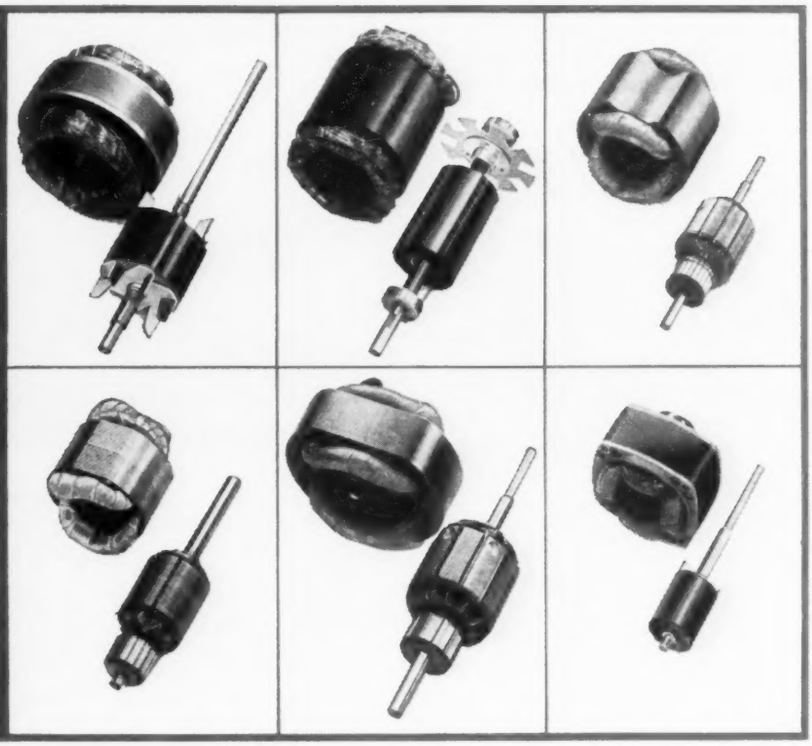
Front panel of the Digital Clock. In addition to time indication, there is a mechanical indication of power failure which can be reset manually. An SPDT contact is provided for remote indication of power failure.

a complete line of HOWARD and New Howard (FORMERLY WESTINGHOUSE) motor parts sets in ratings from 1/200th to 1 h.p.



Illustrated here are a few of the motor parts sets in the complete Howard line. They are currently handling the power requirements of portable power tools, floor polishers juice squeezers and thousands of other widely varied applications. Designed to be built directly into the housings of products and appliances, Howard Motor Parts Sets include armatures and fields, brushes and brushholders, rotors, stators and fans—in any combination, as needed. Whatever your application, there is a standard Howard parts set or variation to match your specifications. If your requirements are in the range of ratings from 1/200th to 1 H.P., check with Howard today.

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SPECIFICATIONS

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Parts Set No.	No. of Slots	Outside Diameter	Inside Diameter	Core Sizes Available	No. of Bars	Insulation	Hubs
11A	11	1.375	¼ 5/16	¾, 13/16, 1, 1¼	11 or 22	paper, mica, bakelite, or nylon	molded or steel
150	12	1.379	⅜	¾, 1, 1¼, 1½	24	paper, mica, bakelite, or nylon	bakelite or steel
200	8	.960	¼	¾, ⅞, 15/16, 1	16	paper or mica	steel
500	12	1.506	.359	¾, 1, 1¼, 1½	24	paper or mica	steel
700	14	1.812	⅜ ½	1¼, 1½, 1¾, 2	28	paper	steel
900	13	1.600	⅜	1¼	26	paper or mica	steel
2700	7	1.380	¼	1, 1¼, 1½	7 or 14	paper or mica	steel or bakelite

ALL MODELS:

SHAFTS:
Shafts are ground from centers for concentricity. Special flats, worms etc., can be cut on shafts if required. C.R. Steel is normally used, however stressproof or various types of stainless steels can be furnished if desired.

INSULATION:
Armatures have a fiber end insulator at both ends of the steel laminations. The inside of the slot is insulated with varnished cambric. The armature is wound with heavy formvar copper wire.

LAMINATIONS:
Laminations are stamped in sets from 24 or 26 gauge improved electrical sheet steel. They are riveted together under pressure in an expanding die. The outside diameter of the field can be ground to customer's specifications. Field coils are wound with heavy formvar copper wire, taped with cotton rayon tape, inserted in field core, then double dipped and baked in an insulating varnish. Field leads can be cut to desired length.

MISCELLANEOUS:
Brush holders and caps with correct brush assemblies can be supplied upon request. Special length cores can be made if required. Armatures can be either statically or dynamically balanced, or both, if required.

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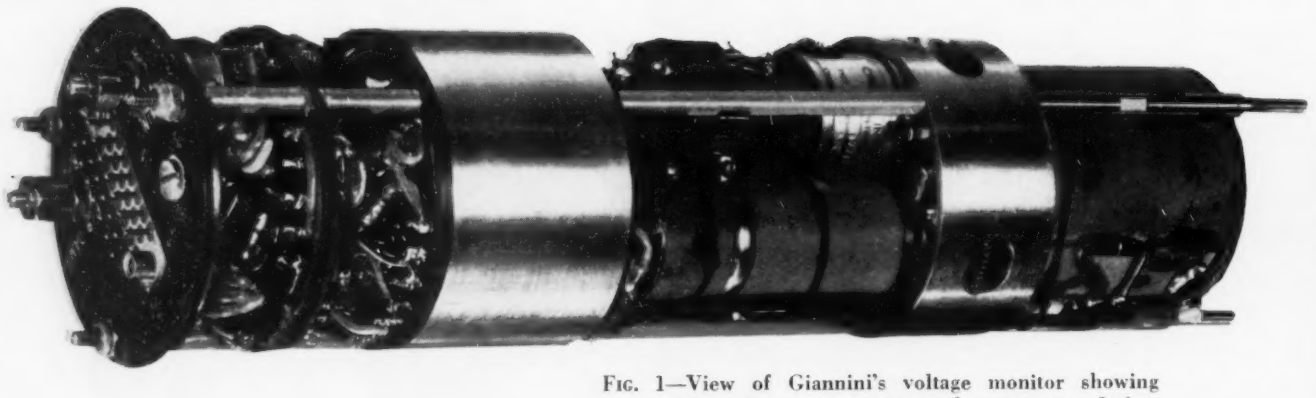

FIG. 1—View of Giannini's voltage monitor showing arrangement of components to produce compact design.

TELEMETRY

Precision Voltage Monitor for Accurate Data Transmission

A technique implemented by a unique electromechanical assembly of gears, servo motor and potentiometers is making possible an improvement in telemetering accuracy of at least two magnitudes. Interposed between the transducers and the telemetry transmitter, in the case of missile-test applications, the airborne unit converts a-c output signals from an airborne data source into three d-c voltages representing the data to four or more significant figures. These three separate units of information are then fed into the telemetry or recording system on three separate channels. If each of these channels can be read within one or two significant figures, which is well within the capabilities of most telemetering and recording systems, the result is transmitted information with an accuracy of four and five significant figures. Without changes in the circuitry of the transmitting system in any way, errors incurred in transmittal are restricted to the fifth and higher order significant figures.

Information on this precision voltage monitor designed by G. M. Giannini and Company, Inc., Pasadena, California, was sent to us by Mr. John M. Rau of the company's New Product Research Group. He said that the unit, designed for the telemetry system of the Chance Vought Regulus II, has inherent accuracy of 0.035 percent and repeatability within 0.01 and makes possible telemetered data with approximately 0.04 percent error over-all. "These figures," he claimed, "were obtained under extended operational conditions, and are conservative representation of the unit's performance including the effects of all error sources such as hysteresis, linearity, temperature effects, and long term drift. Although designed with aircraft and missile flight test instrumentation in mind, the scale-multiplying technique can also be incorporated into any system in which data transmission is a significant source of error."

The unit consists of a servo system driving three potentiometers connected to the servo shaft by gear ratios of 1:1, 10:1, and 100:1 to produce three d-c output signals proportional to the input voltage signal being monitored. Figure 2 further describes the operation of the unit. Figure 1 shows its compact design.

The 100:1 potentiometer completes one revolution for every one percent change in input signal amplitude. The 10:1 potentiometer, completing one revolution for every ten revolutions of the 100:1 potentiometer, acts as a counter of the 100:1 potentiometer revolutions, and at the same time provides the second significant figure of the data. Rotating at a 1:1 ratio, the third potentiometer completes one revolution for a full scale change in output signal amplitude.

Actions of the 1:1 and 10:1 ratio potentiometers can be considered as counting the number of revolutions of the hundred to one potentiometer. What is most significant is that the outputs of the 1:1 and 10:1 potentiometers need only be read to within the first significant figure to provide data accurate to the third and higher significant figures represented by the 100:1 potentiometer.

REDUCING THE ERROR

Since the 1:1 and the 10:1 ratio potentiometers need to be read only to within the first significant figure, any telemetry or data recording system error that would affect the second or higher order significant figure of a given channel reading is now restricted to affecting only the fourth or higher order significant figures of the transducer data, as read from the 100:1 potentiometer channel. Even here the potential accuracy is increased since the fourth and fifth significant figures of the data appear as only the second or third significant figures in this telemetry channel.

Had the servo motor shaft rotation information in the form of a d-c voltage from a single 1:1 ratio potentiometer been fed directly into a single channel of the data handling system, system errors would have affected second and higher order significant figures of the input information. In the configuration where a 100:1 ratio potentiometer is used, therefore, effects of system errors on raw data have been reduced by a factor of one hundred.

Mr. Rau said that the effects of system errors on data accuracy may be reduced by factors other than one hundred by changing the ratios between output potentiometers. Greater reductions call for higher ratios. "However," he pointed out, "use of higher ratios is effective only if the system accuracy is high enough initially to take advantage of them. For example, in the case of a ratio of ten to one between potentiometers, system accuracy must be high enough to permit the first potentiometer to be read within five percent if it is to be used to count the number of revolutions of the ten to one potentiometer. If the gear ratio is increased to twenty to one, the first potentiometer must be read to within two and one-half percent if it is to be used to count the number of revolutions of the twenty to one potentiometer. Increased gearing ratios, in themselves, cannot provide unlimited accuracy. The data source must possess at least the accuracy capability required in the recorded data, and the data handling system must possess that degree of accuracy required to use the

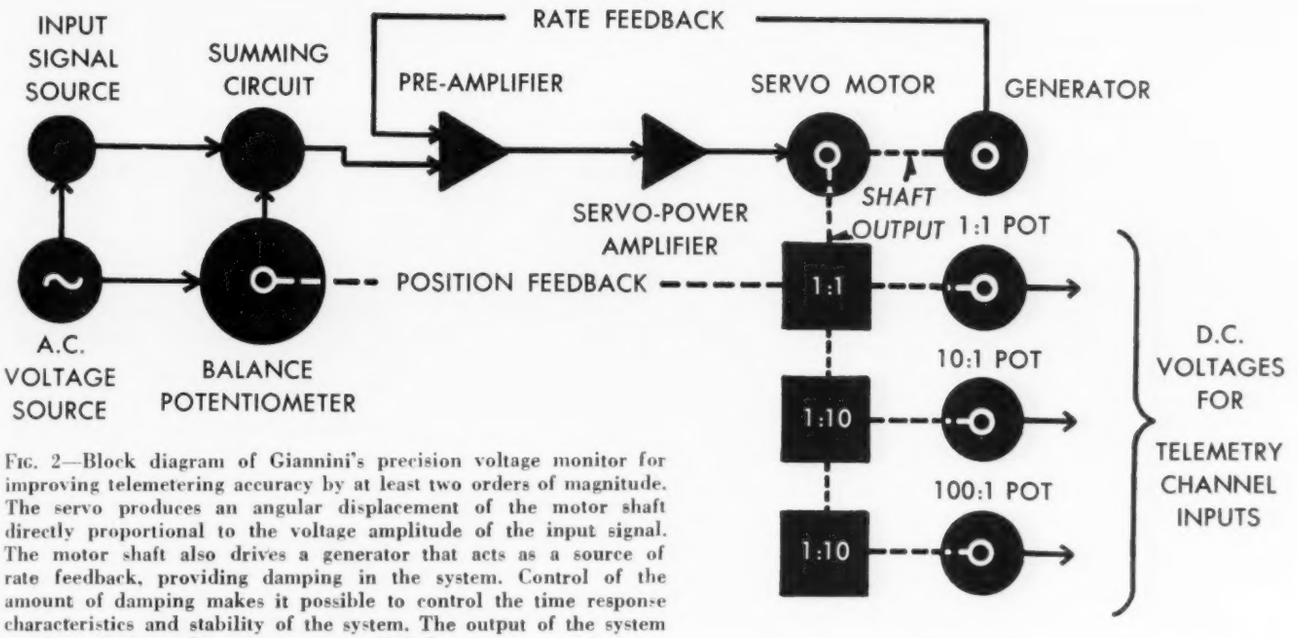

FIG. 2—Block diagram of Giannini's precision voltage monitor for improving telemetering accuracy by at least two orders of magnitude. The servo produces an angular displacement of the motor shaft directly proportional to the voltage amplitude of the input signal. The motor shaft also drives a generator that acts as a source of rate feedback, providing damping in the system. Control of the amount of damping makes it possible to control the time response characteristics and stability of the system. The output of the system consists of three d-c voltages, controlled by three potentiometers connected to the servo shaft by gear ratios of 1:1, 10:1 and 100:1. The output of each potentiometer is fed into a separate telemetering or recording channel. The result is that the potentiometers, each excited by an identical five-volt d-c source, provide shaft-position information accurate to four and five significant figures, when the telemetering system itself is capable of only first and second order accuracy. Higher accuracy capabilities of the telemetry system extend the information accuracy beyond the fourth significant figure.

scale-multiplying technique. The overall objective is to provide the most compatible combination on input data source, data system, and data application. In this respect, the scale-multiplying technique is considered as the means of matching the accuracy capabilities of elements of a complete information system.

DESIGN MINIMIZES SERVO ERRORS

Mr. Rau cautioned that applying conversion techniques to raw data obtained from airborne signal sources to reduce the effects of data handling errors is effective only if the conversion mechanism introduces errors of magnitude much less than those introduced by the data handling system. "To provide data good to the fifth significant figure," he said, "the voltage monitor maintains an accuracy of 0.035 percent with repeatability within 0.01 percent over ranges of inputs from 0.0 to ±0.8 to and from 0.0 to ±100 volts. Designing accuracies of this magnitude into a unit 2¼ inches in diameter and 9½ inches long required exacting investigations into the sources of error and the means of eliminating them."

Giannini designers found that quadrature, caused by distributed reactance in the circuit introducing phase shift, proved to be the most persistent error-producing factor. "Most precision potentiometers," Mr. Rau said, "are designed and tested for direct current applications, and are very susceptible to quadrature error. The balance potentiometer is, therefore, a major contributor to the servo system error. Stray capacitance existing between turns of the balance potentiometer and additioonal stray capacitance introduced by wiring to the transducer produce phase shift between the alternating voltage signal from the input source and the nulling voltage. This phase error in the summing circuit results in a null point shift. Shifts in the servo null point result in amplitude errors in the output." Overcoming this problem by a careful choice of potentiometers and wiring methods, Giannini engineers have made provisions for the effects of particular installations of the unit. Calibration procedures have been developed to permit calibration of a voltage monitor installed in an aircraft or missile to account for any quadrature error introduced by the installation.

Chosen for reliability and ruggedness, the magnetic servo power amplifier is driven by a transistor push-pull stage. Errors due to unbalance in the push-pull stage are eliminated by providing an isolation circuit for the transistor emitter ground. "Use of high gain transistors with low temperature sensitivity and exacting potting techniques have given the voltage monitors operational capabilities over temperature ranges of −65 degrees C to 71 degrees C under vibrational loadings of 15 g's at frequencies of 2000 cps."

OTHER APPLICATIONS

The scale-multiplying technique is adaptable to other applications requiring precision voltage monitoring. "One application that makes full use of the servo capabilities of the monitor," Mr. Rau suggested, "is in the design of a pressure sensor with a feedback loop closed through the sensing element." Output shaft rotation provides pressure data and feeds a force balancing system that mechanically maintains the pressure sensor in its most sensitive range. With the sensing element always balanced in its most sensitive range, the instrument provides an extremely precise source of pressure data suitable for the most exacting altitude computations. The voltage monitor serves also as a means of monitoring temperature sensors, to supply airborne computing systems with both pressure and temperature data required for Mach number and true airspeed computations.

Other applications of the voltage monitor mentioned by Mr. Rau were: driving analog to digital converters to provide airborne digital computers with precise gyro and accelerometer data required in inertial navigation systems, and digitalizing profile-follower informaton in automatic contour milling machines. "With its highly accurate servo and unlimited input and output capabilities," Mr. Rau said, "the precision voltage monitor provides the means of fully using data from the most precise transducers and instruments available today." END

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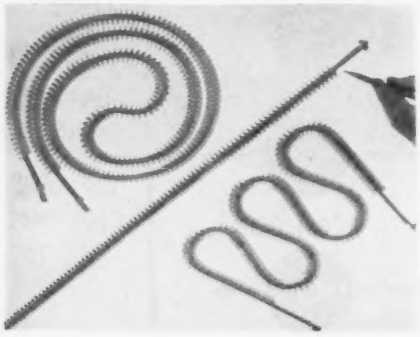
FAST TEMP RISE

Finned Tubular Heaters



A slim, finned tubular heating element for forced convection air heating provides rapid heat-up almost identical with an open coil element, but has the added advantage of totally enclosed and insulated construction. The element is only ¼ inch in diameter and fins are furnace brazed to provide homogenous construction. Called Microfins, they are suited for air ducts and blower type space heaters and are recommended for industrial processes requiring heated air blasts such as ovens and dryers. Because of their formability and relatively high watt density—80 watts per square inch on steel or alloy sheath—they can concentrate output where space is at a premium. Radiating capacity of the fins also permits application where low surface temperatures are needed. Alloy construction has been made available for installations in which corrosive atmospheres are present. Edwin L. Wiegand Co., Pittsburgh, Pa.

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WORTH FILING

Spring Design

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WORTH FILING

Electrical Brake Application

Eight-page Bulletin GET 2770 provides detailed technical data on the application of GE's complete line of a-c and d-c brakes. Contains applications, performance, operation, and characteristics of solenoid-operated, Thrustor-operated, and magnet-operated brakes; 16 performance curves.

Source: General Electric Co.
Schenectady, New York

For your copy: Circle No. 229 on Inquiry Card

WORTH FILING

Electrical Contacts

Sixteen-page catalog describes properties and uses of the Gibson line of electrical contacts; publication aids in selection and application of electrical contacts throughout the broad original equipment field. Applications include alarms, bells and buzzers, contactors, domestic appliances, instruments, rheostats, signaling equipment, sliding contacts, tap changers, thermostats, vending machines, air or oil-immersed circuit breakers, relays, automotive switches, disconnect switches.

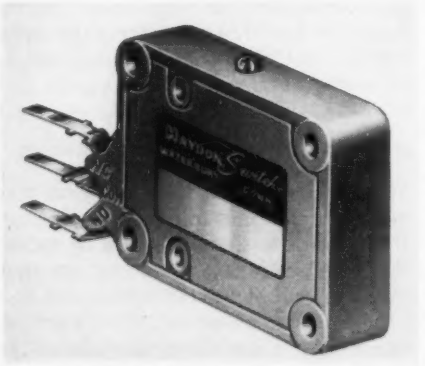
Source: Gibson Electric Co.
Delmont, Pa.

For your copy: Circle No. 230 on Inquiry Card

Electrical Disconnect

An explosive electrical disconnect has been designed for umbilical disconnects or other severing functions in missile operations where guillotine choppers are not feasible. It converts the 55-circuit Bendix pygmy connector into a reusable explosive-actuated device without altering in any way the electrical characteristics of the original connector. Incorporated into the explosive structure are threaded receptacles for two electrical primers which can be of a wide variety of types. Design of the unit is such that the connector is severed by explosion of either or both primers thereby enhancing reliability and permitting selective circuit application if desired. Two shear pins hold the connector seated until it is deliberately fired. Beckman & Whitley, Inc., San Carlos, California.

Circle No. 212 on Inquiry Card



Plastic Switch With New Actuating Principle

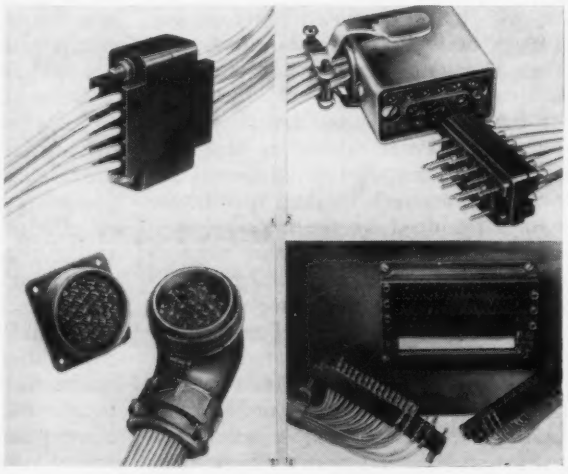
Designed for both military and industrial applications, 10-amp snap-action switch meets stringent requirements of military and commercial users. A new switching principle causes full contact pressures to be maintained closer to the actuation point when switch is actuated or deactuated. This feature makes the switch particularly suitable for applications where the activating mechanism moves slowly, as with thermostatic or pressure elements. Haydon Switch, Inc., Waterbury, Connecticut.

Circle No. 189 on Inquiry Card

Solderless Connectors

A new line of solderless connectors will be displayed for the first time at the IRE show by the Omaton Division of Burndy Corporation, Norwalk, Conn. All connectors have crimped pins and sockets that snap-lock into the plug and receptacle. Upper left: MS miniature type; upper right: 15-contact, multi-purpose plug and receptacle type; lower left: AN-type; lower right: feed-thru, modular design, multiple insert type.

Circle No. 203 on Inquiry Card



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★ 1/5th the usual cost!

★ Design is simplicity itself!

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Replace bulkier, heavier, more complex assemblies with IRC Magnetic Clutches in such equipment as computers, instruments, weighing equipment, speed changers and for other electro-mechanical jobs.

IRC offers you four models for gear and direct-in-line drives in moving coil types. Multi-shaft drives and "custom" units also available. All are D.C. operated. Voltages up to 55. Min. drive torque: 10 in. oz. Max. drag torque: .5 in. oz. Extra high temperature and humidity limits.

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Elasco's MINISOURCE power supplies, fixed or semi-variable, are designed for use with transistorized circuits, instrumentation, computer circuitry, as bias supplies, or any application where good regulation of low voltage is required. They are available for either 60 cycle or 400 cycle operation, for any voltage between 4 and 50 volts, and at current ratings between 50 and 500 ma:

INPUT: 105—125 V AC

REGULATION: better than 0.5%

RIPPLE: better than 0.5%

OUTPUT IMPEDANCE: less than 0.25 ohms, DC—100 kc

POLARITY: grounded or floating operation

TEMPERATURE: compensated from —30 to 65C

PRICE RANGE: $55 — $115 f.o.b. Boston

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ELECTRONIC ASSEMBLY COMPANY, INC.

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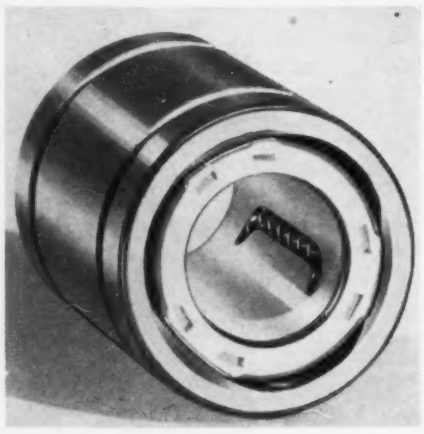
CIRCLE 11 ON INQUIRY CARD

COMPONENTS DESIGN



BALL BUSHING

Low Friction Linear Instrument Bearing

A new type of ball bushing for super-sensitive applications has been developed by Thomson Industries, Inc., Manhasset, New York. These new linear bearings have wide application in many types of instruments and controls where extremely low friction linear motion is specified.

Originally developed to meet the need for an extremely sensitive yet rugged and compact accelerometer, the unit is now used in inertial guidance systems of missiles and aircraft. Inherently, forces perpendicular to the axis of a ball bushing cannot cause linear motion; hence, the bearings enable accelerometer designs with extremely low "cross talk." The re-circulating ball principle used in the bearings provides unlimited travel which enables accelerometers and other instruments to have a wide range.

Threshold sensitivity which can be obtained in any type of component can be computed from the angle down which the bearing will continuously roll. Factory inspection criterion is an angle of 20 minutes or less with a three-ounce weight on the bearing. This angle will decrease if the weight is increased and conversely increase if the weight is reduced.

During the development and testing of these bearings a new method of using them was discovered which enables them to roll down a shaft at an angle of one minute or less. "The application of this new principle," states Mr. John B. Thomson, President of Thomson Industries, Inc., "should lead to new achievements in obtaining near-zero friction and unlimited travel in linear support."

Despite its small size and light weight, the new instrument bearing is very rugged, essential in withstanding high vibration and G-forces present in missiles and some types of aircraft. The ball retainer is actually milled from a solid sleeve making it stronger than the pressed metal retainers used in standard ball bushings. The outer sleeve, which carries the load, is through-hardened to Rockwell 60 C and precision ground to extremely close tolerances on both size and finish.

The construction of the new bearing provides through passages between the ball retainer and the outer sleeve. These passages are in register with the relief side of each ball circuit and permit cleaning solvents to be blown through and the escape of dust particles from the outside as well as the inside of the retainer.

Designated INST-4812, the bushing has a bore diameter of 0.2500 inch +0.0000 −0.0003; nominal outside diameter is 0.5000 inch; length is 0.750 inch; bearing weighs 0.02 pound and has a rolling load rating of 13 pounds and a static load rating of 22 pounds; bore diameter and the O.D. are concentric within 0.0005 T.I.R.

Circle No. 180 on Inquiry Card

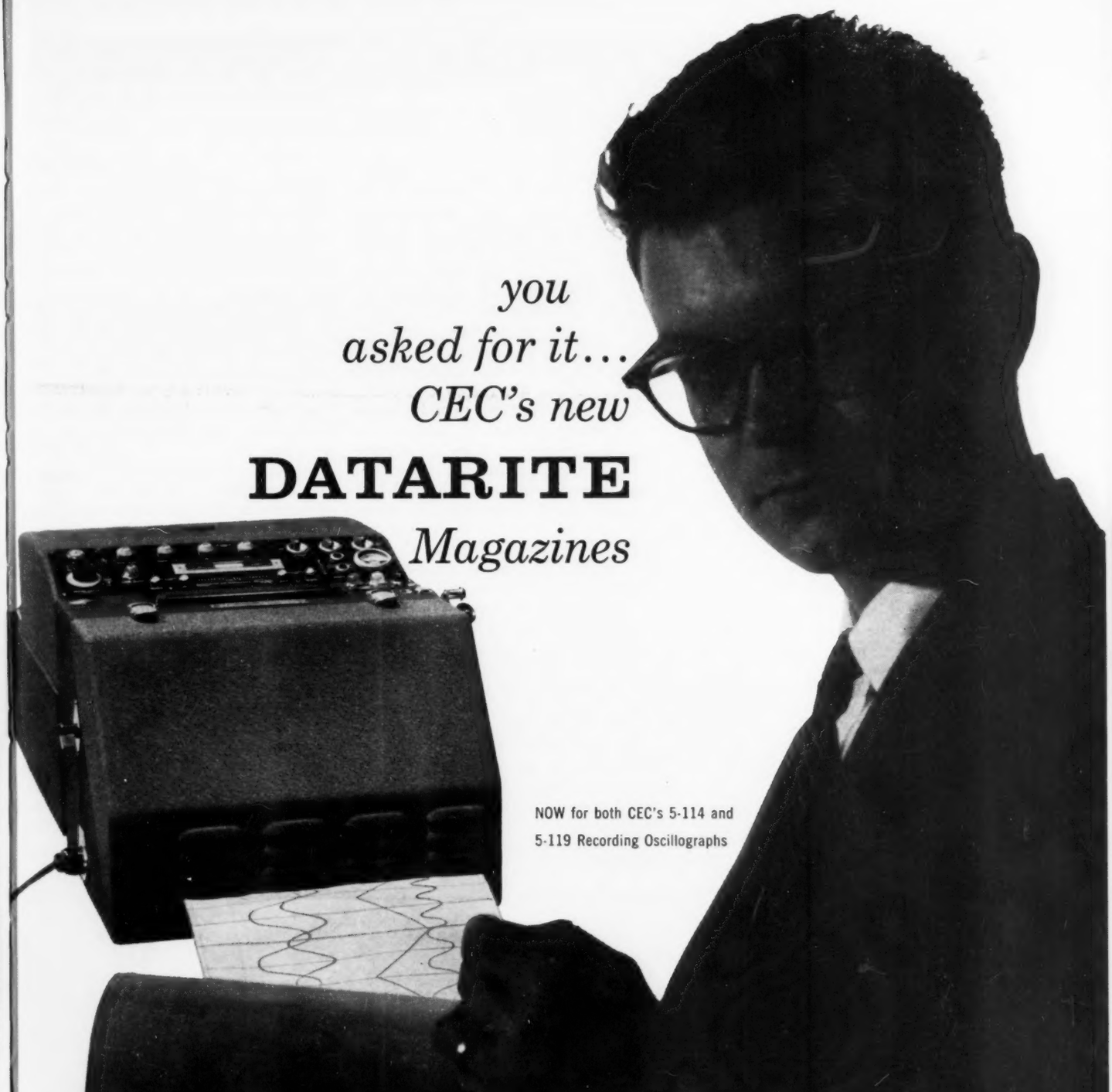
MINIATURIZED CRYSTAL FILTERS

Miniaturized crystal filters in four bandwidths at a center frequency of 10.7 Mc permit single conversion with high selectivity in the early stages of the receiver close to the antenna. Test installations revealed marked reduction in receiver desensitization as a result of this feature. Designed to meet present and future FCC selectivity requirements, this entire family of filters are interchangeable both mechanically and electrically to simplify production and eliminate the possibility of receiver obsolesence.

Specifications: center frequency: 10.7 Mc; shape factor: 2:1; insertion loss: approximately 1 db; size: 2⅜ inch x 1 inch x 1 1/32 inch. Hycon Eastern, Inc., Cambridge, Massachusetts.

Circle No. 196 on Inquiry Card

CIRCLE 12→



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DATARITE magazine Type 5-047 attaches directly to the versatile 5-114 and Type 5-036 attaches directly to the 5-119 Recording Oscillograph without modifications or adapters. Magazines hold 400 ft. of thin-base recording paper. Record and event numbers are automatically imprinted for ease of data reduction. For complete DATARITE details contact your nearby CEC field office, or write for Bulletin CEC 1598-X13.

Descriptive literature on CEC's Recording Oscillographs: Type 5-114 (18 and 26-trace models, 7-inch record width) Bulletin CEC 1500-X21. Type 5-119 (36 and 50-trace models, 12-inch record width) Bulletin CEC 1536-X25.

Consolidated Electrodynamics

300 No. Sierra Madre Villa, Pasadena, California

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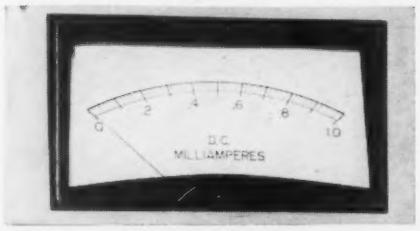
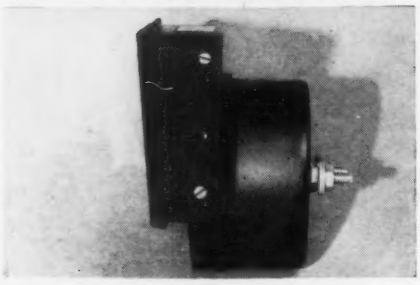




NEW PANEL METER DESIGN

A different approach to panel meter design results in better visibility of the instrument itself and in improved appearance of the equipment in which it is used. The new design reduces the amount of error caused in D'Arsonval meters by magnetic mounting panels since the magnet pole pieces are in back of the panel, not in the same plane with it. Whereas the magnetic error is around 5% in many meters, it is about 1% in this design.

The new meter improves the appearance of original equipment by exposing only its indicating area. Its face is flat instead of bulging, as is the case with "edge-wise" meters. Approximately one-third of the round barrel enclosing the meter movement extends back of and below the rectangular dial section. The movement, the face and the pointer are tilted back 6 degrees from the vertical front of the meter to reflect glare upwards making the dial easier to read. Across the top of the dial section is a strip of translucent plastic intended to transmit light to the dial, if desired, from a source in back of the mounting panel and above the meter.

In a panel, the meter rests snugly on a flange running around the back of the dial section. The black Bakelite housing has screw holes for attaching brackets that hold the meter tightly in place from the back side. No positioning holes need to be drilled in the panel. The meter can easily be inserted from the front into any rectangular panel opening that fits the dial section which measures 5 inches by 2-⅞ inches; the depth from the flange to the end of the barrel is 2-1/3 inches. The unit is available in virtually any range of sensitivity. Assembly Products, Inc., Chesterland, Ohio.

Circle No. 213 on Inquiry Card

Solid Tantalum Electrolytic Capacitor

Solid tantalum electrolytic capacitors, primarily designed for use in miniaturized circuitry where both reliability and temperature stability are vital factors, are commercially available in 18 ratings. Five *tan-TI-cap* capacitors are six-volt units ranging from 22 to 200 microfarads, five are 15-volt devices from 10 to 100 microfarads, five are 25-volt capacitors from five to 55 microfarads, and four are 35-volt units from four to 25 microfarads.

Featuring a high degree of temperature stability and extremely long shelf and service life, *tan-TI-cap* capacitors offer original equipment manufacturers several ratings significantly higher than most other miniature tantalum capacitors. These include units with ratings of 200 microfarads at six volts and 100 microfarads at 15 volts, stability within 10 percent of rating from −80 degrees C to plus 85 degrees C, and plus or minus 20 percent capacity tolerances at 25 degrees C.

Mechanically, the *tan-TI-cap* capacitor provides a solution to many of the major space and mounting problems for designers of miniaturized circuitry. The case, which is cylindrical and without a protruding lip, measures only 0.358 by 0.173 inch for the smallest device and 0.700 by 0.264 inch for the largest. Its clean design permits vertical or horizontal mounting on printed circuit boards within a minimum of space.

The unique construction of *tan-TI-cap* capacitors permits maximum ratings in small packages. *Tan-TI-cap* capacitors are constructed of a solid pellet of pressed and sintered tantalum powder with an integral wire lead. The dielectric is formed by a tantalum-derived coating deposited electrochemically on the pellet, resulting in a semiconductor-type junction with the solid electrolytic. The pellet is solidly embedded within the case to withstand high and low frequency vibrations and high impact.

To facilitate printed circuit board mounting in close spaces, the leads of all *tan-TI-cap capacitors* can be bent sharply in any direction because the leads and welds are anchored within the case. All leads are guaranteed to withstand a three-pound pull in any direction for up to 30 seconds. The solid construction of *tan-TI-cap* capacitors eliminates one of the major causes of failure in other miniature capacitors, that of leakage. Because *tan-TI-cap* capacitors contain no liquid or paste material, they cannot leak.

Original equipment manufacturers' prices in 100 and up quantities begin at $1.80 each for the six-volt capacitors; $1.86 each for 15-volt devices; $1.75 each for 25-volt units; and $1.83 each for the 35-volt series.

In addition to *tan-TI-cap* capacitors, the Semiconductor-Components division of Texas Instruments, Inc., manufactures the industry's widest line of germanium and silicon transistors, and silicon diodes and rectifiers, precision resistors, and high purity silicon material.

Circle No. 187 on Inquiry Card

Explosion-Proof Dual Switch Temperature Control

This control, Type D98A, is a sensitive, remote bulb temperature control designed for use in hazardous locations where explosive vapors and gases are present. Two separate switches permit switch action above or below the set point, control of two independent circuits and flexibility of switching arrangement.

Temperature settings are made by rotating calibrated knob over a graduated barrel. Individual adjustment of switches is accomplished by independent recessed hex-head screws which standardly provide for an approximate 15 degree F span, constantly maintained throughout the control range between switch settings.

Thermal system consists of a bulb, capillary, and bellows filled with temperature sensitive liquid. The bellows expands or contracts with heating or cooling, thus actuating a snap-action switch at a preset temperature point.

Standard head compensation provided, is effective from −65 degrees to +160 degrees F. United Electric Controls Co., Watertown, Massachusetts.

Circle No. 200 on Inquiry Card

PROBLEM:

Servicing the "heart" of a low, desk-mounted chassis.

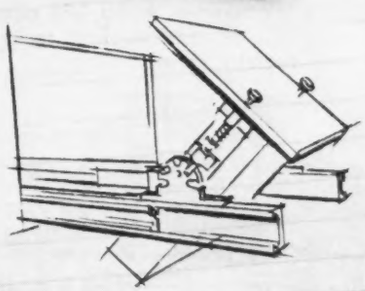
SOLUTION:

Specification of Grant tilting slides to pivot the chassis over for "on-top" servicing.

The Soroban Engineering Company recently completed a repackaging program of their Perforated Tape Sequencer for Digital Control of Analogue Computers. This sequencer is a vital component of the Automatic Digital Input-Output Device (the ADIOD System) used at the White Sands Proving Grounds in New Mexico. Tape readers and their associated equipment are mounted within the desk, on Grant three-section tilt slides. These provide quick accessibility to every part of the chassis. Some of the equipment requiring servicing and adjustment is mounted underneath the chassis and Grant Slides are used to tilt the unit, bringing the bottom-mounted equipment into the view of the operator for easier servicing.

Grant No. 363-P2Y Slides
recommended for
loads up to 200 lbs./pair

Courtesy Soroban Engineering, Inc.



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STAFF COLUMNIST

Emile Labin

Emile Labin is President of Automation-Electronique-Recherche Opérationelle in Paris, France.

Report from France

EDDY CURRENT DEVICES

An eddy current slip coupling consists of two main parts, one coupled to a rotating driving input shaft and the other to the shaft of a driven machine. These two parts are separated by an air gap; there is no mechanical contact between driven and driving members.

When the field assembly, which in modern couplings has a stationary coil, is mechanically rotated, the iron ring or bell forming the driven member remains stationary until excitation current is applied to the coil. With the coil energized, relative motion between the driving magnet poles and the iron of the driven bell or drum creates eddy currents in the parts of the bell lying opposite the poles (teeth and slots). These induced currents produce a second magnetic field which combines with the first to produce a torque on the driven member of the coupling.

The value of this torque depends both on the strength of the rotating field and the difference in speed (slip) between the two members, as expressed by the following formula:

$$T = k\, i^{\alpha}\, n^{\beta}$$

where
i is the excitation current,
n the slip in the rotations per minute, and
the values of α and β are roughly 2 and 1/2 respectively. Controlling the excitation of the coupling controls both torque and slip, and thereby speed.

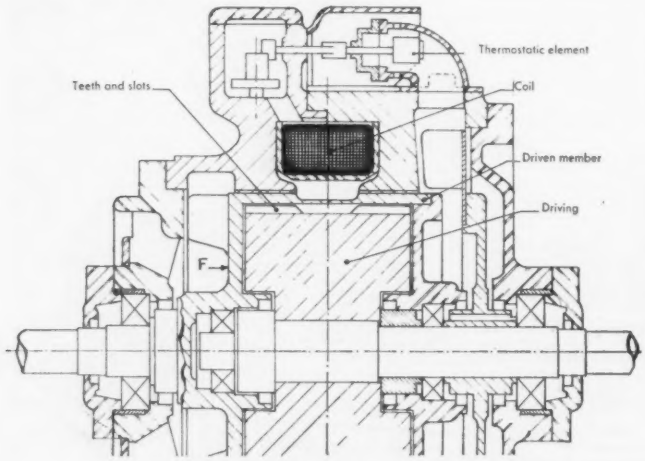

FIG. 1—Flameproof eddy current coupling.

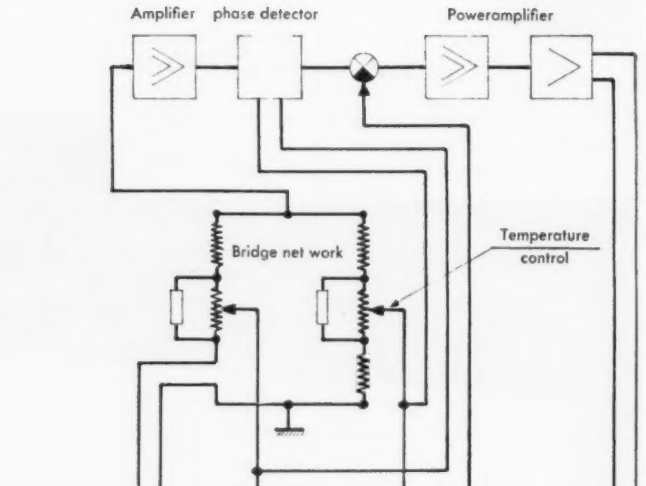

FIG. 2—COPPER MILL COILER. Winding a sheet of copper in a copper mill requires variable control of both speed and tension to close tolerances and between wide limits at will. However, with a given work the winding power is invariant. Once tension and linear speed have been chosen, it is only necessary to vary the speed of the drum, reducing it as the winding diameter increases. Thus the power to be delivered by the coupling is

$$P = C\,\omega = \text{constant}$$

where
C is the winding torque and
ω is the angular speed of the drum.
Control of the coupling thus requires measuring C and ω and multiplying them. Torque can be measured on the driving motor side, since the torque supplied by the squirrel cage motor is always equal to the torque transmitted by the eddy current coupling. Or it can easily be obtained from a measure of the active power absorbed by the motor by means of an electrical circuit as represented by block (RE1). The output of the power (torque) measuring circuit is a d-c current proportional to the torque. This current is employed to control the field of a separately excited tachometer generator (DT), driven from the shaft of the winding drum. The d-c output voltage of the dynamo is thus the required product of speed and torque. This product is compared in a known way with a d-c power-reference voltage and the difference is used to drive an amplifier for controlling the excitation field of the coupling. Two control potentiometers (P2) and (P3) are used for setting any required tension and speed. It can thus be said the system contains a measuring device, a computer, a controller, and a servo motor, all linked in a closed loop control. A 150 HP motor is used in this operation.

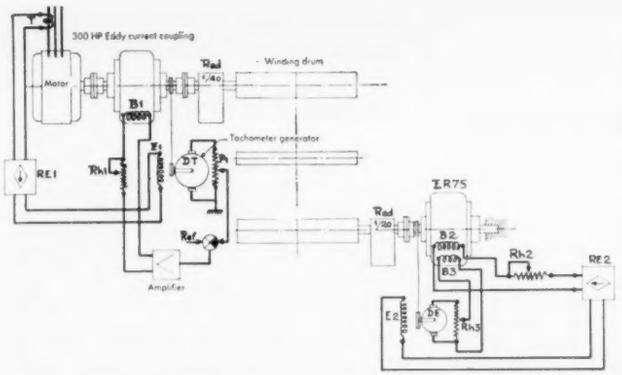

FIG. 3—AUTOMATIC TEMPERATURE CONTROL. A large chemical plant requiring precise control of room temperature in its shop uses a variable speed drive with an Elcotron air cooled coupling to control the speed of a 300 HP fan driver. The temperature to be controlled is measured by a bridge circuit based on use of a non-linear resistance (thermistor). Supplied by a 100 cps stabilized a-c source and employing a phase sensitive detector stage, the bridge furnishes a d-c output voltage proportional to room temperature. This voltage is compared in the usual way with a reference voltage to obtain the difference. The difference voltage is amplified and used to control the speed of the fan by varying the excitation of the Elcotron coupling. Proportional control is obtained by use of tachometer feedback to avoid the tendency of such high powered systems to acquire "on-off" control characteristics.

An eddy current slip coupling is thus a torque transmitter. When it is used as a variable speed drive the generation of torque is always accompanied by a loss of energy in the form of heat. For a given torque these heat losses are directly proportional to the difference between input and output speed. An efficient cooling system is thus a problem of primary importance in the design of eddy current couplings.

The cooling medium is either air or water. Air cooled couplings are usually preferred by users, but water cooled types must be used to dispose of large amounts of heat, as in large units on constant torque applications.

Although the principle of these couplings has been known for some time, their use has been expanded only in recent years. One French company, Sté ELCO, 89, rue Bobillot, Paris 13me, whose chief activities have been the manufacture and sale of eddy current devices, known here in France as Elcotrons, has produced a flameproof coupling, believed to be unique in design, for use on variable speed drives in coal mines both in France and Great Britain.

As can be seen in Fig. 1, this Elcotron coupling has a stationary coil and is of the homo-polar type. The coil itself is wound on a metallic non-magnetic former which fits tightly into the stator in compliance with existing standards for flameproof enclosure of electrical apparatus.

The bell-shaped iron output member is entirely enclosed while the inner rotor, the driven member, is designed so that the unoccupied volume within the bell is minimum.

A fan is used to drive a stream of air over the heated surfaces. Since the flameproof enclosure is designed for operation within the rating of the apparatus, a thermostatic device is used to de-energize the coil when for some reason the rating of the apparatus is exceeded.

These and similar couplings are used in a great number of applications where speed control or torque control are required. Two such applications are described in Figs. 2 and 3.

END

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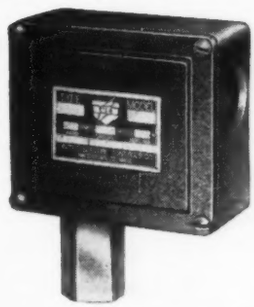
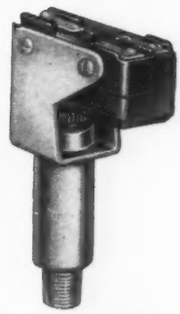
Multi-Purpose

PRESSURE CONTROLS J7 | J40

▶ Enclosed-TYPE J7





▶ Skeleton-TYPE J40

These controls are compact, precision-built, rugged and inexpensive. Type J7 is ideal for controlling air, gas or liquid pressures up to 500 psi . . . Type J40 for pressures up to 250 psi.

Adjustable Pressure Ranges	J7 . . . various models cover ranges between limits of 0 and 500 psi J40 . . . various models cover ranges between limits of 0 and 250 psi
Switch Ratings	15 amps or 20 amps at 115 or 230 volts A.C., also D.C. switches upon specification
Switch Types	N.C., N.O., or Double throw, no neutral position
Electrical Connections	J7 . . . screw type terminals on switch standard J40 . . . solder type terminals on switch standard
On-Off Switch Differential	Fixed and uniform throughout specified range is standard
Mounting	J7 . . . ¼" NPT female, brass fitting standard J40 . . . ⅛" NPT male, brass fitting standard
Variations	Design variations are available upon specification
Applications	On industrial equipment and engine applications . . . marine, aircraft or special purpose

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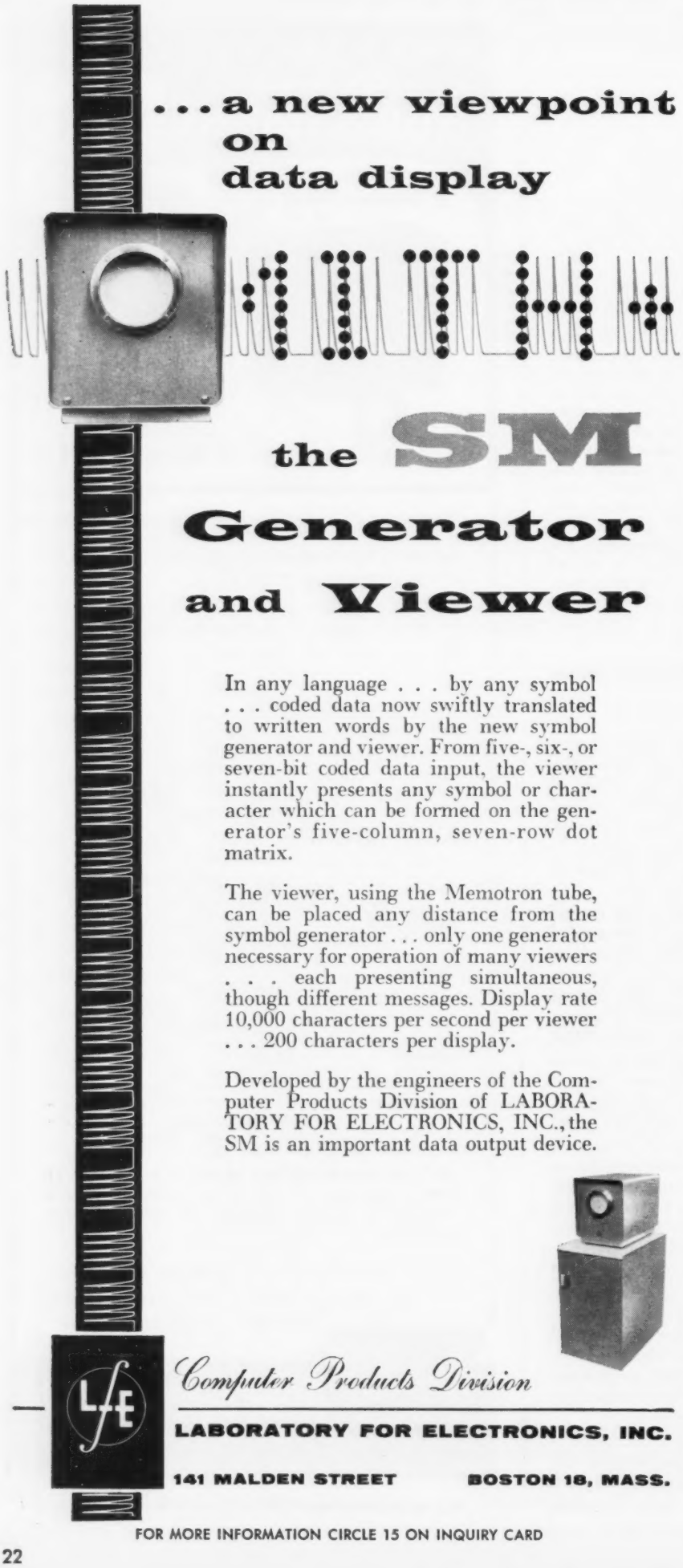

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Developed by the engineers of the Computer Products Division of LABORATORY FOR ELECTRONICS, INC., the SM is an important data output device.

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Computer Products Division

LABORATORY FOR ELECTRONICS, INC.

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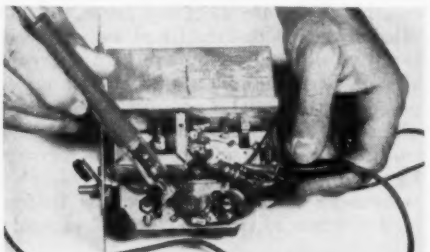
COMPONENTS-DESIGN

Versatile Circuit Tracer

In the under $5.00 price class this circuit tracer offers continuity tracer for dead circuits, low voltage live circuit testing, and high voltage live circuit testing. Shown in the illustration is the circuit tracer used as a continuity tester. Under this set up the Circuitracer is powered by two small pin light batteries and a signal light built into the tip of the tool shows that the user has a closed circuit. Hunter Tools, Whittier, Calif.

Circle No. 198 on Inquiry Card

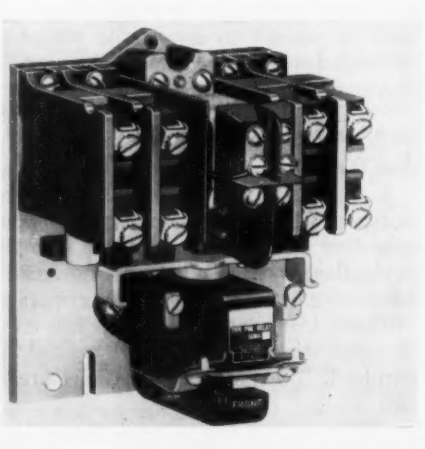


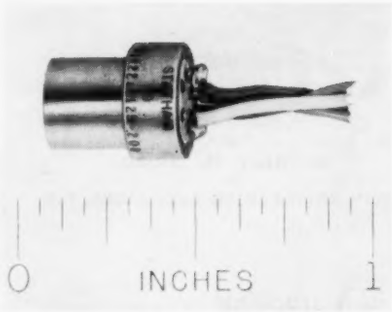
Latch Relay Needs No Extra Vertical Height

Mechanically-held latched-in relays without vertical height disadvantage permits magnetic and latch relays to be grouped in rows as desired without waste of panel space. The latch unit occupies the space of only two poles. Since the latch unit coil is designed for continuous duty, it is not necessary to use a relay pole to cut out and protect the tripping coil.

Latch unit wearing surfaces are nylon on phenolic. Contact carriers are nylon, and the linkage between contact carrier and magnet is floating so no vibration or shock is transmitted. Clark Controller Co., Cleveland, Ohio.

Circle No. 191 on Inquiry Card





Tiny Pressure Transducer

A tiny new flush diaphragm pressure transducer, approximately ⅛ the size of miniature instruments, has a diameter of 0.25 inch, measures 0.47 inch in length and weighs three grams. Because of these extremely small dimensions, the unit may be adapted to almost unlimited application possibilities for the measurement of gage, differential and absolute pressures.

Using the principle of the unbonded strain gage, the circuit of the instrument forms a complete bridge with a nominal resistance of 200 ohms. It has an output of approximately 15 millivolts full scale open circuit at three volts excitation. The wide ambient temperature limits of −100 degrees to +275 degrees F and the availability of pressure adapters for conversion to closed line applications extend the potential use of this instrument.

Its accuracy particularly suits it for such exacting uses as airload measurements, wind tunnel models, as well as a wide variety of other installations. Statham Instruments, Inc., Los Angeles, California.

Circle No. 197 on Inquiry Card

Hi-Temp Magnetic Clutch

Designed to meet rigid environmental specifications, this magnetic clutch is size 11, 1.062 inches in diameter, single-ended and magnetically actuated. Clutching torque is conservatively rated at 16 ounce-inches, with three watts of d-c applied to the control coil. Concentric input and output shafts (shaft through shaft) are located at the synchro mount end of the unit. Flat faced couplings have minimum angular displacement upon engagement. Voltage ratings range from 1.5 to 300 volts d-c, with 24 volts standard. Dynamic Instrument Corp., Westbury, L. I., New York.

Circle No. 201 on Inquiry Card

AIRBORNE TAPE RECORDER

Magnetic Tape Recorder operates at altitudes up to 100,000 feet and in temperatures from —55 degrees to +100 degrees C. Instrument accepts both the standard NARTB 10½-inch or special CEC high-performance reels; available in 7 or 14 track models, using ½- or 1-inch tape respectively. Power supplies are contained within the 12⅞ x 25 x 7-inch case. Consolidated Electrodynamics Corp., Pasadena, California.

Circle No. 193 on Inquiry Card

LOW VOLTAGE—HIGH CURRENT DC SUPPLY

This Q 6-2 Nobatron is one of a new series of all-transistor low-voltage, high current DC Supplies now available from Sorensen & Company, Inc., South Norwalk, Connecticut. They feature tubeless circuitry, low ripple, fast response, transient-free performance, adjustable output, wide frequency range and complete self-protection.

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push-pull
CONTROLS
Compression & Tension Type
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Three Types:
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Positive remote controls for actuating mechanical, hydraulic or other devices. Eliminate bell cranks, pulleys and dual cables. Patented U. S. A. All world rights reserved. Send for ENGINEERING MANUAL giving detailed prints and complete specifications covering materials, finishes, capacities. Please address Dept. EMD 58.
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FOR MORE INFORMATION CIRCLE 16 ON INQUIRY CARD

A SMALL OPTICAL TRACKER

Gardner H. Sloan
DUNN ENGINEERING ASSOCIATES, INC.

Here is an optical tracking system with a one-cubic-inch tracking head that can follow an extremely weak source, such as a light spot on a C-R tube, at 5 cps within one milliradian tracking error. The tiny tracking head makes it possible to use a miniature gimbal system for driving it.

Systems developed for special purposes in research programs often have other potential uses, but in cases where the original purposes thoroughly warranted the development, further exploitation of the equipment is sometimes overlooked.

An infrared or optical tracking system designed at the Instrumentation Laboratory, Massachusetts Institute of Technology for a special type of radar simulator uses three circuit techniques applicable to radiation tracking and servo systems in general.

- A low frequency lag network, consisting of two resistors and a condenser, that increases the gain at low frequencies resulting in much smaller velocity and static errors without changing transient response or reliability
- A coherent detection system, usable where systematic fluctuation of target signal is available, that picks out small error signals in a large amount of noise, discriminates targets according to frequency and phase, reduces drift in the photocell
- Push-pull circuits that cancel pick-up in photocell leads.

Starting with radar development at MIT Radiation Laboratory, Gardner Sloan has worked on sonar systems, fire-control and inertial-guidance systems, and missile-control and guidance problems. He received an M. S. degree in Physics from MIT in 1947. His work on the optical tracker was in partial fulfillment of the requirements for the degree of Electrical Engineer in the Department of Electrical Engineering at Massachusetts Institute of Technology.

FIG. 2—Optical components of the tracking system.

GENERAL DESCRIPTION

The angle-tracking system includes an elevation servo and a deflection servo to position the tracking head, and automatic gain control to keep the loop gains of these servos essentially constant as the target moves in range. A block diagram of the system is shown in Fig. 1.

A light modulator drives the target lights with a 90-cycle square wave of voltage producing a small 90-cycle modulation in the light intensity. The light arriving at the tracking head goes through a converging lens and falls on a lead sulfide photocell (Fig. 2).

The photocell is a square array of four sensitive areas each 1/16 inch square separated from each other by approximately 0.01 inch. Voltage obtained from these cells is proportional to variation in light falling on them.

The difference in voltages from the two horizontal cells is the deflection error signal and that from the vertical cells is the elevation error signal. The 90-cycle component of each difference signal is amplified and demodulated to form a d-c error signal. The d-c error signal then passes through networks designed to improve the performance of the servo. The d-c signal from these networks modulates a 400-cycle carrier which is amplified and used to drive the servo motor. In the deflection servo, a tachometer is available to improve the servo performance.

Amplitude of the error signal in each loop for a given angular error is proportional to intensity of the light falling on the photocells. Since the range may change by a factor of 20, the intensity

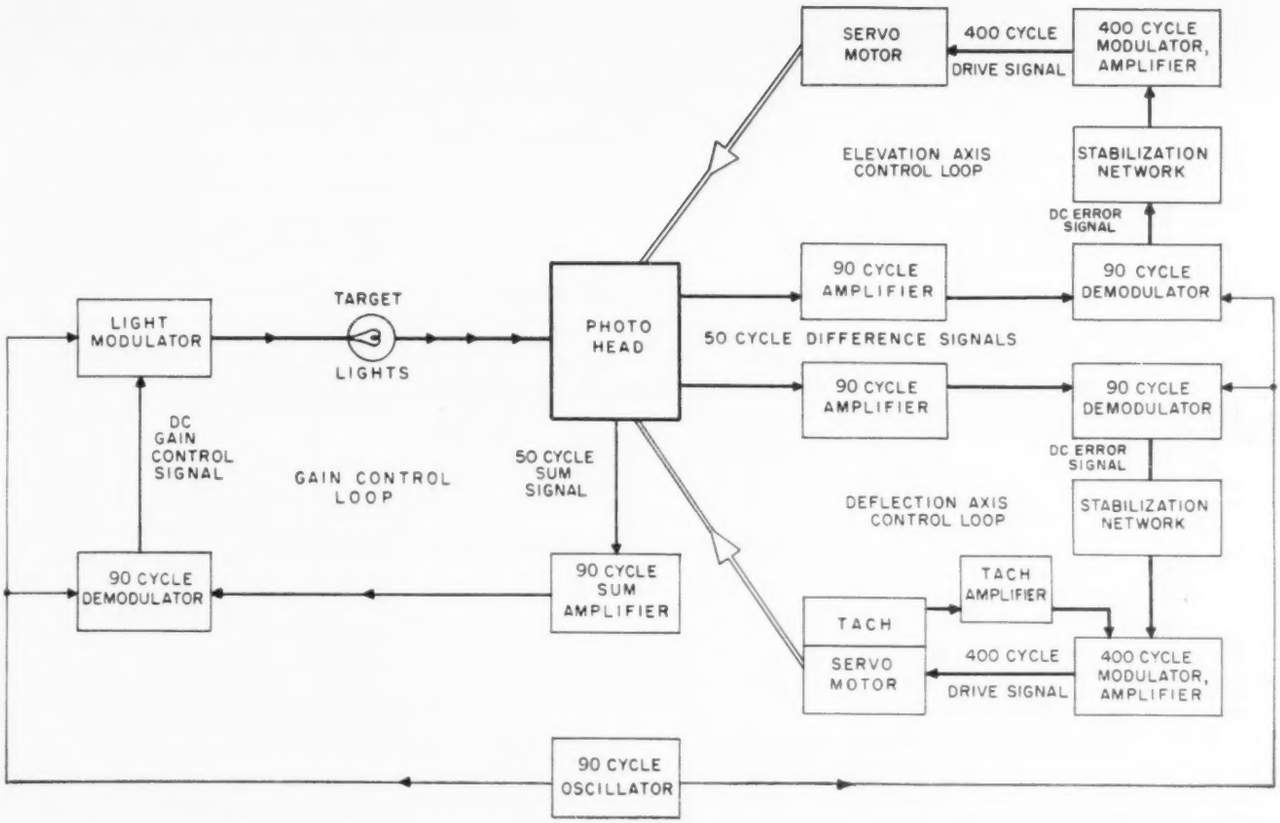


FIG. 1—Block diagram of the angle tracking system. Angle tracking in two axes is performed with a photoelectric system. The light from grain-of-wheat lamps on the target is focused by a lens on a lead-sulfide quadrant cell in the tracking head. The target lights are modulated at 90 cycles and the error signals are demodulated, filtered, and converted to 400 cycles to drive the servo motors. Automatic gain control keeps the signal strength at the photocell constant as the range of the target varies. The average error of the tracking system is about one milliradian and the bandwidth is about five cps. The sizes of target and tracking head are about one cubic inch.

may vary by a factor as high as 400. This variation in intensity results in similar change in the servo loop gains. Whereas the difference of the photocell voltages is used to form the error signal, the sum of the voltages is used to form the gain control signal. The 90-cycle component of this sum signal is amplified, demodulated, and used to control the amplitude of the 90-cycle square wave which drives the lights.

LIGHT INTENSITY MODULATION

Although much greater signal strength is available from the quiescent or d-c component of the light, usual drift problems not only of d-c amplifiers but also of photocells themselves preclude the use of unmodulatel light as the signal carrier in the angle-tracking servo. Furthermore if the d-c component of the light were used as a signal carrier the servo would just as likely track a hot soldering iron, a cigarette, or a hot servo motor as the desired target. Use of a particular modulation frequency enables the servo to recognize and track a particular target.

Because of the long thermal time-constant of the filaments in the incandescent bulbs which constitute the target, the modulation percentage of the light varies approximately as the reciprocal of the modulation frequency. Ninety-cycle modulation was chosen as a compromise between the low-frequency advantage of greater signal strength and the high-frequency advantages of ease of amplification and greater possible servo bandwidth. Furthermore the precaution was taken of choosing a modulation frequency sufficiently removed from 60 cycles so that the servo would not respond appreciably to the difference frequency.

LIGHT SOURCE

A large variety of light sources were tested in an attempt to find the best light source for the angle tracking system. Among them were neon bulbs for small size and ease of modulation, mercury and helium-argon bulbs for more ultra-violet light, and bits of heating coil and soldering iron tips for more infrared radiation, as well as incandescent bulbs for more total radiated power.

Selection of the light source is dependent on the photocell and lens system with which it is to be used. The photocell and lens eventually chosen for this system are a lead sulfide cell and a quartz lens.

The best light source for this system is a model railroad lamp made in Japan and called a grain-of-wheat lamp. It is exceptionally bright for its small size and excellent for modulation because of its fine filament wire. Usable signals at modulation frequencies as high as 200 cycles were obtained in preliminary testing of this lamp. One of these lamps is shown unmounted in Fig. 2.

Another type of light source which may be used with the tracking head is obtained from a cathode ray tube. The spot on a P7 screen, intensity modulated at 90 cycles, gives an acceptable tracking signal at a distance of about a foot from the tracking head. The servo response of the tracking system can be checked for various simultaneous inputs in both axes by having it

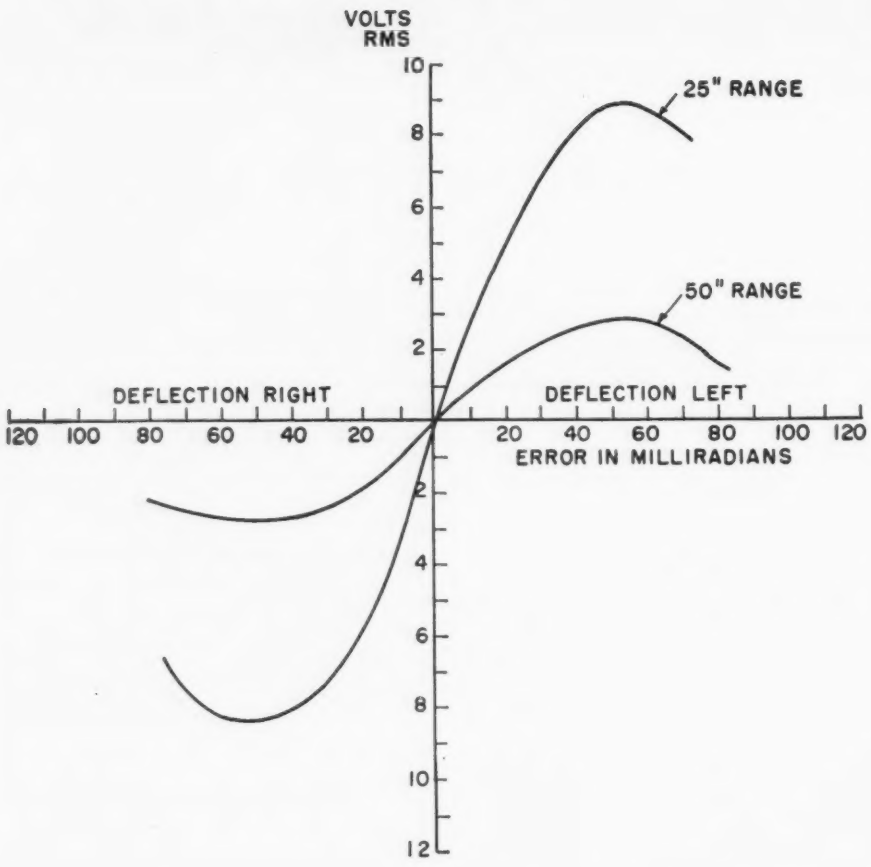


FIG. 3—Error signal from photocell amplifier versus angular error for two values of range without automatic gain control.

From the standpoint of servo design the image should be somewhat defocused so that it will cover the dead zone between the photocells to give a smooth curve of error signal versus angular error such as that shown.

The figure also shows the effect of range on the angular gain of the tracking head, the gain in this case decreasing by a factor of 3 when the range is increased by a factor of 2. This is not as fast a change in gain with range as is to be expected from the square law. Furthermore, for a given range the angular gain decreases as the photocell is moved toward the lens. These results indicate the possibility of eliminating or at least reducing the change in gain with range by proper adjustment of the distance between the photocell and the lens.

Suppose the photocell is positioned for the best focus when the target is at maximum range. Then the increase in gain due to increased intensity will be partially cancelled by the decrease in gain due to defocusing as the range decreases.

Further analysis of this problem shows that at best the gain can be restrained to change inversely as the first power of the range. For this reason automatic gain control is a necessity if the servo loop gains are to be even approximately independent of range.

follow a lissajous pattern on the scope.

LENS DESIGN

The design of the optical part of the tracking head is essentially accomplished by specification of its size. One cubic inch of volume is neatly filled by a lens of 1-inch diameter and 1-inch focal length. Reduction of either of these dimensions would give a lower signal-to-noise ratio in the error signal channel because the signal power in the optical image is proportional to the area of the lens and the deflection of the image (for a given angular error) is proportional to the focal length. Hence from the standpoint of signal-to-noise ratio at the photocells the ultimate accuracy of the tracking system is proportional to the volume of the tracking head.

Of the many lens aberrations, only spherical and chromatic aberrations are important in this application. Aberrations such as coma, astigmatism, curvature and distortion were not considered in the design of the lens, because in this problem the target will never be more than a few milliradians from the optical axis.

The chromatic aberration is important because the lead sulfide cell is sensitive to a fairly wide range of wave lengths, from 0.3 microns in the ultraviolet to 3 microns in the infra-red. Fortunately, however, the index of refraction of the lens varies over this range only 1 or 2 percent depending on the material used, leaving only spherical aberration to be minimized.

To maximize the signal strength at the photocell a quartz lens was used. Designed to have minimum focal length under the conditions of minimum spherical aberration, its characteristics are:

Diameter	*1 inch*
Focal length	*0.86 inch*
Double Convex Radii	*0.5 inch, 2.37 inches*
Index of Refraction	*1.458*

PHOTOCELL

The lead sulfide cell used in the tracking head is far superior to the photoemissive type in sensitivity and size and far superior to the photo-transistor type in size at least. In fact this lead sulfide cell has worked so well for the purposes of the tracking system that no attempt has been made to find a better type, although other types such as the cadmium sulfide cell are known to exist, and new developments in this field are being reported almost daily.

The lead sulfide cell, as stated before, is sensitive to a band of wave lengths from 0.3 micron in the ultraviolet to 3 microns in the infrared. The sensitivity of the cell is proportional to its impedance, the impedance of the one discussed here being about 200 K.

The maximum allowable voltage across the cell is equal to 300 times the square root of the product of the cell resistance in megohms and the cell area in square centimeters. For the photocell used in the tracking system, this maximum voltage is about 21 volts. The voltage for best signal-to-noise ratio is equal to half the maximum voltage or about 10 volts in this case.

Since the cell resistance changes in proportion to the light intensity falling on it, the maximum signal is obtained by connecting it in series with an equal resistance. Hence the lead sulfide cell is connected in series with a 220-k resistor and a 22 1/2-volt battery. The B+ voltage cannot be used for the photocell circuit because it contains too much ripple.

A model of the lead sulfide cell is shown mounted on the plastic cylinder in Fig. 2. A model was used for the photograph to eliminate the possibility of damaging the real cell with flood lights. The sensitive surface is separated into four quadrants by spaces about 0.01 inch wide, giving four individual cells with one common termi-

nal, the base plate, in an area 1/8 inch square. There is no reason why a cell could not be made much smaller than this with a 0.001 inch dead zone between the cells.

ARRANGEMENT OF LENS AND PHOTOCELL

Several factors influence the arrangement of the lens and photocells. Some factors are based on principles of optics, others on principles of servo design.

To minimuze spherical aberration the lens is designed and used so that the light is bent an equal amount at each surface. Hence, since the target is always much farther away from the lens than the photocell, the side of the lens that bulges the most (has a smaller radius of curvature) points toward the target. If the image is blurred by moving the photocells toward or away from the lens with respect to the position of best focus, moving the photocells toward the lens will give a brighter image with less loss of definition than will moving them away.

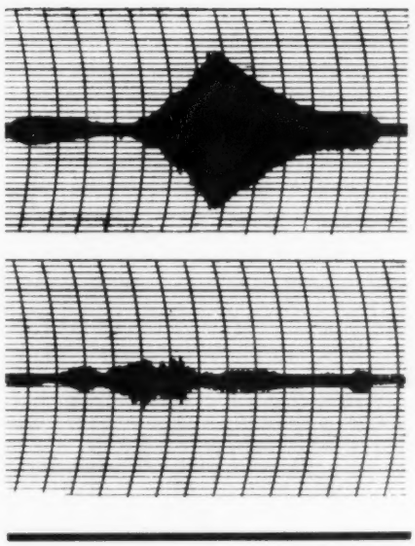
PHOTOCELL AMPLIFIER

The input circuit of the photocell amplifier is a push-pull phase-inverter circuit. Push-pull circuitry is used because the error signal level is about 1 mv, and about 80 mv of 400 cycles is picked up in the 15-ft. cable. Since one lead picks up about the same voltage as the other lead, approximately 90 percent of this pick-up is cancelled by the push-pull circuit. The same principle applies to the smaller amount of 60-cycle pick-up, but unfortunately cancellation of the 60-cycle pick-up does not occur for exactly the same setting of the balance potentiometer as does cancellation of the 400-cycle pick-up. Hence, the balance potentiometer in the input stage is set to compromise between minimum 400-cycle and 60-cycle pick-up and symmetry of the error signal as a function of error.

Push-pull circuitry is also required farther along in the amplifier for minimum ripple in the demodulation circuit, and hence is used throughout the amplifier. Phase inversion is required because for a small angular error the signal from the unilluminated photocell drops to zero and the other photocell signal needs to be phase inverted to form a good push-pull signal.

DEMODULATOR

The best method of detecting small signals in the presence of noise is by coherent detection which consists of beating the signal and noise mixture with a continuous wave of large amplitude known to be in phase with the signal to be detected.



A chopper circuit in the tracking system acts in a manner closely approximating ideal coherent detection and delivers to the d-c network a full-wave rectified form of the 90-cycle error signal. The fundamental ripple component of the full-wave rectified error signal is 100 cycles, which is very effectively removed by a bridge T network. The higher harmonics are reduced by the 2.0—μfd condenser shunting the output of the bridge T network. The size of the condenser was adjusted for optimum servo performance and insertion of this filter in the error signal channel considerably reduces the servo noise for a given gain setting.

Following the filter is a low frequency lag network with break points at 0.0066 and 0.31 cycles increasing the loop gain of the servo by a factor of 47 for low frequencies. The effect of this lag network on the tracking error during a straight-line crossing course is shown in Fig. 4.

The output of the d-c networks is chopped by a 400-cycle chopper operating at the proper phase to form a drive signal for the servo motor. The 400-cycle signal is amplified by several stages and sent to the appropriate servo drive amplifier.

SERVO DRIVE AMPLIFIERS

The photocell amplifiers and the demodulator circuits of the elevation and deflection channels are the same, but the servo drive amplifiers are different because different motors are used.

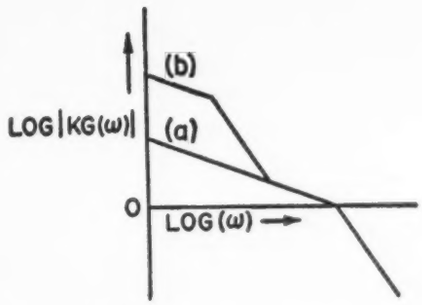


FIG. 4—Effect of low frequency lag network on tracking error during a straight-line crossing course. The angular velocity of a target on a straight line crossing course has a shape versus time similar to the envelope of the error signal in (a). This velocity error is greatly reduced by the introduction of a low frequency lag network as shown in (b).

Each drive amplifier consists of single-ended stages, a phase inverter, and a push-pull output stage matched to the motor impedance. Voltage feedback is provided to reduce the source impedance as seen by the motor. Impedance matching is desirable for power economy in the output stage, but low impedance is desirable for speed of response. Some servo motors will run single phase if the control winding is connected to a high impedance source.

The capacitor shunting the control phase of the motor satisfies the relationship:

$$X_C = X_L + \frac{R^2}{X_L}$$

where X_C is the reactance of the capacitor and $R + j X_L$ is the impedance of the motor. This relationship means that the amplifier is loaded with a maximum impedance and operates at unity power factor.

AUTOMATIC GAIN CONTROL

The automatic gain control amplifier amplifies the 90-cycle sum signal from the photocell amplifier and demodulates it to form a d-c control signal which is applied to the light modulator. A fraction of the filament voltage is used to cancel the 60-cycle pick-up at the input of the amplifier which would otherwise saturate the final stages of the amplifier.

The 90-cycle gain-control signal is demodulated in the same manner as the tracking error signal. The d-c gain-control signal is filtered by an RC network with a time-constant of one second and is applied through the 90-cycle light-modulating chopper to the grid of a 6V6 in the light modulator chassis.

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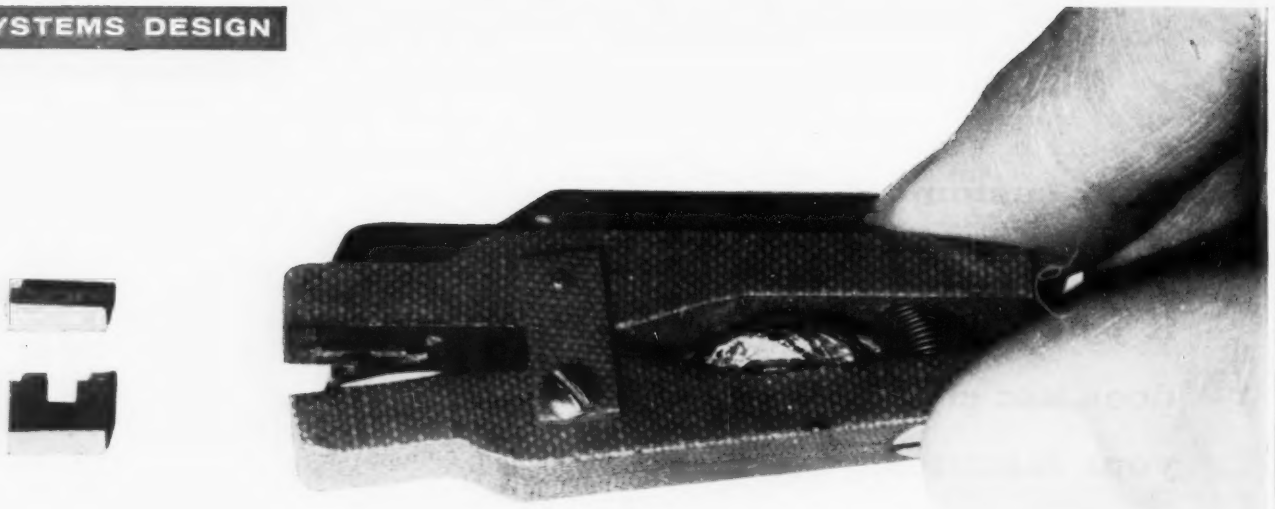


Close-up view of clamp type probe. Core without windings shown at left. The core of the transformer consists of 0.014-inch silicon-steel laminations. It is formed of matching C- and I-shaped sections; the I's close the gap of the C's when assembled. The completed core is 5/16-inch square, ⅛-inch thick, and contains a ⅛-inch window. The core is mounted in a spring-loaded bakelite clamp, about the size and shape of an ordinary clothespin. The legs of the C project upward from the lower jaw of the clamp, while the I is contained in the upper jaw. A pin passes through the center of the I, providing rotary movement in the plane of the jaws, so that the I will seat itself properly on the projecting legs of the C as the clamp closes. The matching faces of these parts are ground. Shielding with mu-metal minimizes sensitivity to external magnetic fields. The core C contains two windings, each having 250 turns of number 44 enameled wire. The four coil leads connect to a shielded four-wire cable and plug. One of the windings on the core is considered the secondary and provides the actual current pickup. The other winding, the tertiary, is part of a feedback network to provide frequency equalization. By using this tertiary winding, transformer output for a particular primary current is very nearly linearized over the frequency range from 100 cps to 100 kc. The primary of the transformer is, of course, the conductor carrying the current to be measured.

INSTRUMENTATION

A Clamp-Type A-C Microammeter, Transistorized

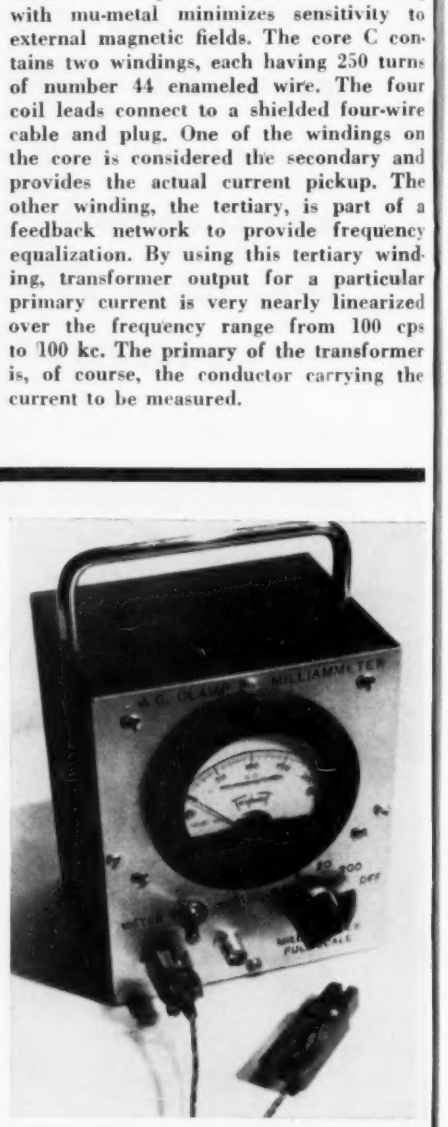
A portable, battery-powered, transistorized microammeter developed at the National Bureau of Standards provides a rapid, convenient method for measuring small alternating currents. Since the current pickup is a miniature split-core transformer that can be clamped onto a wire, it is unnecessary to open the circuit to make the measurement. Lowest range of the prototype instrument is 200 microamps full scale, and on higher ranges it can accurately determine currents as large as 200 ma. Its frequency range is 50 cps to 100 kc. Instruments embodying the same principles can be used for materially lower and for very much higher ranges. The development was carried out as part of the work in basic instrumentation, a cooperative program sponsored by the Department of Defense, the Atomic Energy Commission, and NBS, and was conducted by G. F. Montgomery and C. Stansbury of the Bureau's electronic instrumentation laboratory.

For many years, it has been common practice to extend the range of current-indicating instruments by using current transformers. For convenience, the transformer often consists of a secondary winding on a split core that can be clamped around the conductor carrying the current to be measured. This technique suggested a similar device for measuring small currents at audio and radio frequencies: an instrument consisting of a small clamp-type magnetic probe and a suitable means for amplifying the probe output to operate an indicating meter. Such an instrument would be complementary to the vacuum-tube voltmeter found in all experimental electronic laboratories. The Bureau's device is not only based on the probe-amplifier-meter concept but is transistorized as well for long life and modest power requirements.

PERFORMANCE

Whenever current is measured with any type of instrument, an impedance is in effect inserted in series with the circuit carrying the measured current. For the Bureau's microammeter, the insertion impedance is almost entirely resistive over the useful frequency range. This impedance is made up of a resistance of 2.8×10^{-5} ohm and inductance of 2.2×10^{-7} henry in parallel.

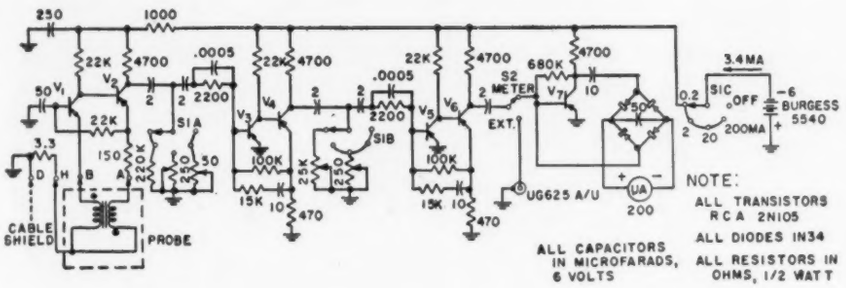
In the experimental instrument, the high-frequency limit is imposed mainly by limitations of the transistors used, although even with high-frequency transistors the maximum operating frequency is probably not more than three or four times the transformer resonant



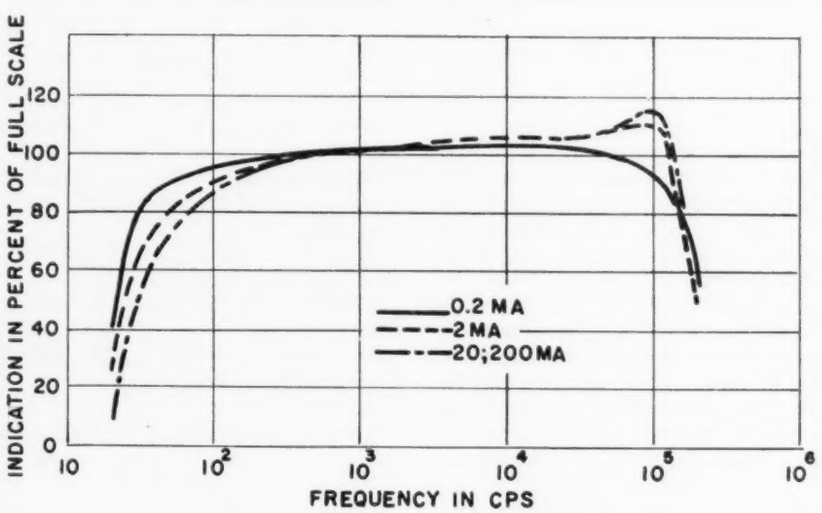
Photograph of a-c microammeter with clamp-type probe developed at the National Bureau of Standards. Probe is in foreground.

frequency of 120 kilocycles. Instruments designed particularly for high-frequency use would probably make use of more appropriate core material and a construction minimizing distributed capacitance.

Another possible application of the general technique used in this instrument is with current transformers for high-voltage power lines, using single through-type primary conductors. However, this application has not been investigated.



Schematic diagram of microammeter. Output of the transformer is fed into a preamplifier consisting of two transistors and a feedback network. Gain in this stage is sacrificed to provide frequency equalization and to reduce phase shift at the higher frequencies. Gain is provided by two intermediate stages, each using a pair of transistors. Each stage uses direct coupling from the first transistor to the next. A feedback network, from the emitter of the second transistor to the base input of the first, stabilizes the d-c operating point for each pair and reduces the overall current gain of each stage to about 20. The a-c feedback factor at low frequency for each stage is about 100; the low-frequency current gain is thus stabilized against transistor and battery aging, and the frequency range for constant response is extended beyond that available without feedback. The indicating meter has a 200 microamp d-c movement and was chosen as a compromise between cost, sensitivity, and ruggedness. The meter is driven through a full-wave rectifier. Although the input current from the intermediate amplifying stages is more than adequate to drive the movement to full scale, it is small compared to the normal operating characteristics of the rectifier. The rectifier, therefore, is operating in a non-linear region. However, the non-linearity is effectively reduced by a one-transistor amplifier whose gain is sacrificed to provide negative feedback through the rectifier. Linearity of response of the entire instrument is within the 2 percent specification of the indicating meter itself, and shows that the degree of feedback in the meter network is adequate.



Response of microammeter over a wide frequency range.

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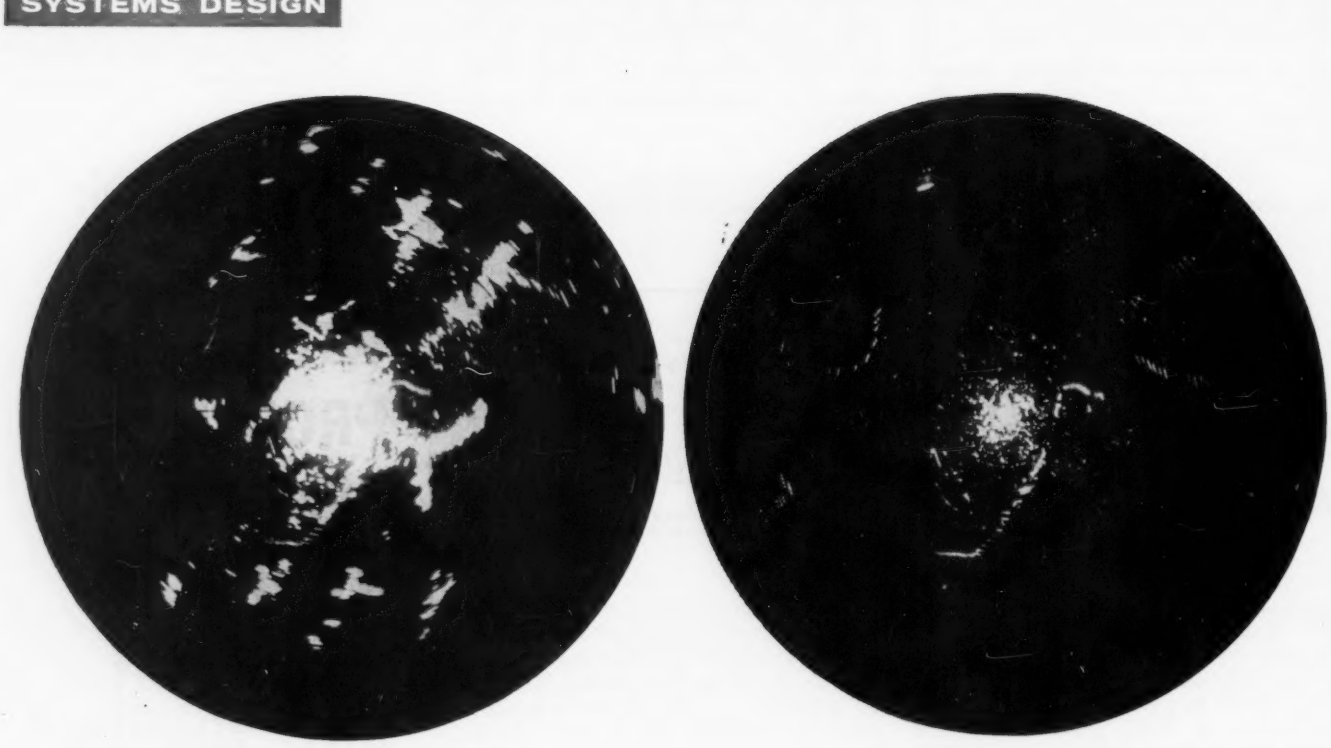


Left: Diversity Radar scope picture without Moving Target Indicator equipment. Right: The Intec Diversity Radar with Moving Target Indicator (MTI) eliminates fixed echoes and gives a clearer image.

FREQUENCY-DIVERSITY RADAR

Improving Radar Displays

Radar displays are subject to various permanent or temporary phenomena that reduce the sharpness of echoes being followed. These phenomena are fixed echoes seen as bright blotches more or less concentrated in a zone around the radar station, and spurious signals, such as background noise (usually non-recurrent), which appear as a spotted background considerably lowering the contrast of the echoes. A display is also subject to interference when two neighboring stations clash.

The Compagnie Generale de Telegraphic sans Fil of France found certain solutions to these problems that merit attention:

- Improvement of signal-to-noise ratio by operating in frequency diversity or by means of devices that correlate the useful signals.
- Suppression of fixed echoes (or signals from targets having a definite radial velocity) by means of eliminators using memory tubes.
- Elimination of spurious signals by an equipment designed to deal with the random nature of background noise.

Production models of radar systems incorporating these innovations are being made available in this country through Intercontinental Electronics Corporation (INTEC) of Mineola, N.Y.

Transmission engineers have long been aware of the principle of diversity operation of radio equipment and of its practical application to long-distance links. Equipment can be operated in either "space" or "frequency" diversity. In the former case, several receiving antennas are used on the same frequency; in the latter transmission and reception are carried out simultaneously on several frequencies using a common antenna. The two systems can of course be combined.

In either system the best signal available at any given instant is selected from two or three received signals by automatic change-over switches.

Theoretically the same principle can be applied to radar, but space diversity is found difficult in practice because of the necessity of maintaining synchronism of operation and especially of antenna rotation. Frequency diversity can be more conveniently applied to radar.

In this application two or three transmitter-receivers operating on different frequencies use a common antenna, possibly with a relative time delay of a few micro seconds. A special hyper-frequency switch is then needed to feed the transmitter pulses to the common antenna, and the echo pulses to the appropriate receiver. The pass band of this antenna must also provide the same radiation characteristics for the two or three operating frequencies.

On reception, the signals reaching the two or three receivers must be resynchronized by compensation of the relative delay introduced at the transmitter.

It only remains to make the best possible use of the video signals thus synchronized.

It would be possible to select the best signal at any given instant and to use that signal alone, but in fact this method would not take advantage of the increased mean power available from several transmitters, or of the increased range provided as compared with a single transmitter of similar characteristics.

A more complex use of the video signals is advantageous.

Consider, for instance, the case of three transmitter-receivers supplying video signals a, b and c. The following alternatives are possible.

- Add $a + b + c$
- Add the video signals in pairs and multiply the partial sums, so as to obtain a signal of the form
$$(a + b)\ (b + c)\ (c + a)$$
- Obtain the partial products and add them together to obtain a signal of the form $(ab + bc + ca)$.

The first solution is naturally the simplest. It is also the solution that

gives the most marked improvement in the signal-to-noise ratio since the echoes appear at the same instant on all three video stages while noise peaks that are erratic and independent are only occasionally superimposed. This system has an obvious disadvantage—the video sum is subject to interference occurring on any one of its three video stages.

In this respect the second and third solutions are more satisfactory. If one of the three video stages is subject to interference, video *a*, for instance, multiplication will remove that interference in the absence of signals on video stages *b* and *c*. The simultaneous use of two or more frequencies is then an excellent anti-interference arrangement effective both against jamming and against interference originating from the transmissions of neighboring stations. In any case, INTEC engineers claim, with any or all of these methods a notable improvement in coverage is secured.

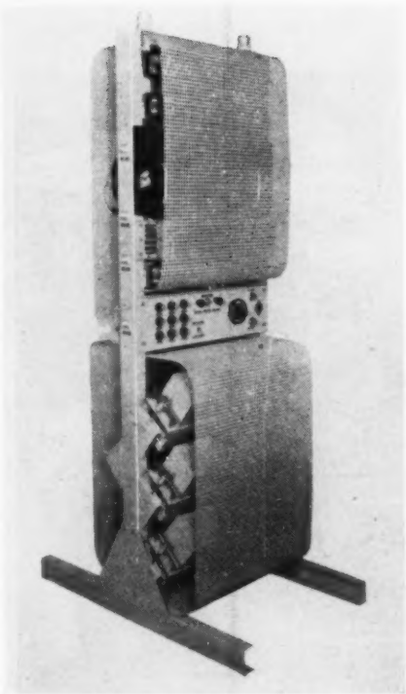
For 90 percent detection curves, range is increased by 30 or 35 percent compared to the range of a single station having the same characteristics and there is a marked increase in the detection percentage at equal range. In fact, they say, apart from a weak zone at the edges of the reception lobe, the detection "blanks" completely disappear. In addition fluctuations due to variations in the echo surface areas of a target are practically eliminated. It can be said then that a station equipped with three transmitters of power *P*, diversity coupled, is, from the point of view of an assured 90 percent detection coverage, equivalent to a single radar transmitter of power 3*P*.

INTEC engineers claim further that almost 100 percent reliability of operation is secured with a twin transmitter-receiver installation and, of course, with three transmitter-receivers, since such an installation continues to function with one unit out of action for purposes of maintenance or repair. They point out that it would therefore be advantageous to apply the diversity principle to any installation for reasons of reliability.

Tests carried out by the French Air Force over long periods on the first experimental diversity radar station developed by CSF were reported to have favorably impressed specialists from many countries.

SUPPRESSION OF FIXED ECHOES

Another improvement in a radar display achieved by CSF was the elimination of echoes from fixed obstacles such as hills, overhead lines and so forth, which confuse the PPI display and always impair watch-keeping.



Interference suppressor unit built by CSFR.

The methods used are well known and are abundantly described in the technical literature. They have been divided in two main groups: "coherent" systems in which the IF signals are made to beat with a reference oscillation initiated at each transmitter pulse and having a certain phase difference with respect to the local oscillator, and "self-coherent" systems in which use is made of beats between superimposed fixed and moving echoes.

In either case a memory element is necessary to compare the amplitudes of the beat signals from one pulse to the next.

The "coherent" equipment built by CSF consists of a memory tube which replaces the more conventional delay line elements.

The advantages of this method, used by the French Air Force over a long period of experimental trials, are

- Simplicity of adjustments—those of the cathode ray tubes.
- Stability of adjustments—no frequent touching up.
- Possibility of varying the radar repetition frequency, the tubes' memory being available at any time and at any desired rate.

This device is designed for adaptation to transmitter-receivers equipped with a stabilized local oscillator, with the possibility of adjusting it to the various intermediate frequencies of the radars. In the case of installations not thus equipped, an additional unit containing a stabilized oscillator can be substituted for the radar's local oscillator.

CSF has also developed an experimental "self coherent" device at present undergoing systematic trials.

COINCIDENCE SELECTOR

On the principle that noise is of a random nature while echoes appear over several consecutive radar cycles and at a practically constant distance (the distance changes from one rotation of the antenna to the next but only slightly during sweep of the beam over the target), it was theoretically possible to boost echoes with respect to noise.

As for the elimination of fixed echoes, a memory element is necessary to compare the video signals obtained during successive repetition cycles of the radar. The memory element developed by CSF is a special tube of the "barrier-grid storage" type, having sufficient definition to allow the whole of the discrimination of the radar to be retained.

Known as "coincidence selector" or "interference suppressor", the device can be incorporated in any type of radar so long as its circuits and memory unit are suited to the characteristics of the main equipment. It ensures the elimination of all nonrecurrent signals as well as of recurrent signals with a repetition frequency different from that of the unit.

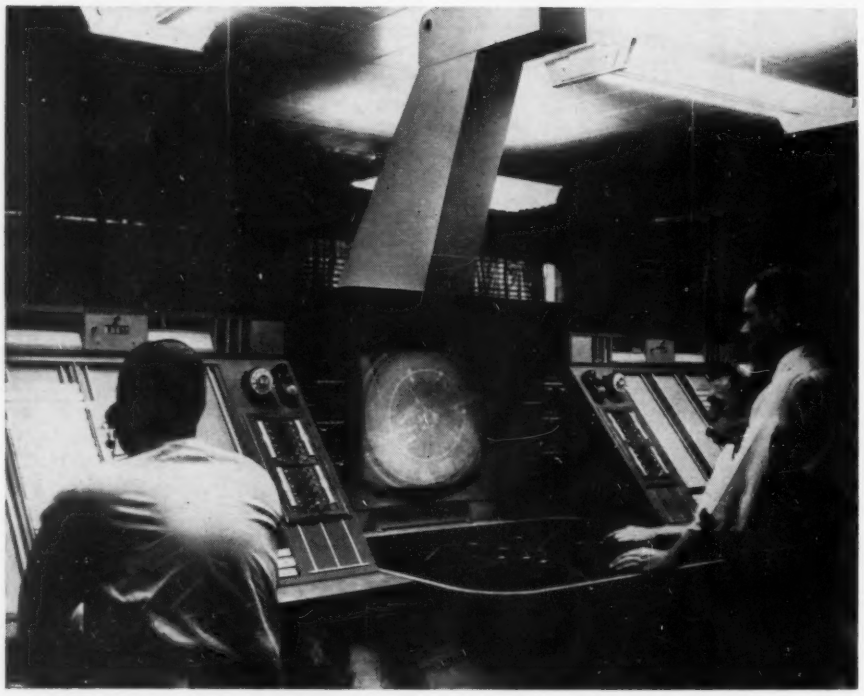
There are two industrial versions, one in sealed containers, designed for mobile stations, the other rackmounted for installation under cover.

It is difficult to quote a performance figure for interference suppressors. Although they do not enhance the sensitivity of the radar, they considerably improve the signal-to-noise ratio by the practically complete cancellation of noise as soon as the echo exceeds noise level.

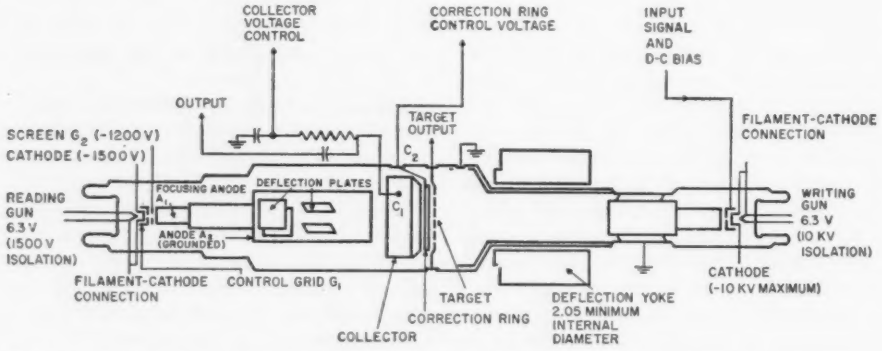
In practice, improvement in the video signals on the PPI displays results from a picture of high contrast on a completely dark background. Watch is thus considerably eased. In addition, screen remanence is generally sufficient to ensure that the four or five preceding echoes produce a visible trace permitting evaluation of the course and even of the approximate speed of the aircraft.

Adjusted for elimination of strong interference, the device permits easy following of a situation that would otherwise be cluttered with interference.

Circle No. 178 on Inquiry Card



Superimposed panoramic radar display (SPANRAD), tested at CAA's Technical Development Center at Indianapolis, combines radar display and operations board image on same TV picture tube. Overhead box contains Vidicon TV pickup for obtaining image of board. Scan conversion permits daylight viewing of transformed radar information on conventional TV receiver.



Video transformation tube TMA-403X provides a controllable link between the radar and television circuits. It employs two axial opposed guns in a single cathode ray tube. One gun writes radar information with its electron beam on an internal target membrane. The other gun reads TV information from the target membrane. It is a semi-conductor-type storage tube in which the two guns are arranged to allow instantaneous transformation of video signals from one coordinate system to another (polar to rectangular) through simultaneous and non-synchronous scanning of both sides of the target membrane. At the center of the tube is a target collector group. The group consists of a collector C_1, a correction ring C_2, and a target membrane similar in operation to a mosaic screen. The reading gun charges one surface of the target membrane to approximately the potential of collector C_1. A thin aluminum film on the other surface of the target membrane is attached to a metal ring at the output of the target, which is at ground potential. Due to the proximity of these members, C_1 is held at a safe potential to prevent breakdown of target insulation. The correction ring is used to reduce the level of the parasitic shading signal. This signal appears in camera tubes having a secondary emission greater than 1. Voltage of C_2 is approximately equal to that of C_1. The exact value is determined experimentally for each installation. The output signal, in the order of a millivolt for a load impedance of 2,000 ohms, provides a maximum useful current of 0.5 micro-amperes. Output signal of the target group can be read from 15 seconds to over 2 minutes before erasure of written information; this, however, is a function of the operating point of the tube. Storage is controlled by voltage applied to the collector, writing-beam current, and reading-beam current. The target is erased by reversing the voltage relationship between membrane and collector.

SCAN CONVERSION EQUIPMENT

Intercontinental Electronics is also currently introducing a procedure called SPANRAD based on scan conversion equipment. Scan conversion equipment takes conventional radar information and converts it into a composite television signal permitting direct viewing on a conventional TV receiver. Advantages claimed for the system over conventional PPI radar display are:

- Controllable video transformation tube retains target information, allowing the operator to see the past track of an aircraft and predicting its future position (memory characteristic).
- A bright display is obtained that permits viewing in full daylight (conventional radar displays normally require a darkened room for viewing).
- A wide variety of relatively inexpensive studio TV equipment is locally available for use with the scan conversion equipment.
- It provides higher resolution than the PPI (no blooming of target echoes or sweep trace).
- Transformed radar picture may be transmitted from one control center to another by conventional microwave equipment or coaxial cable.

For its writing function the scan converter requires radar trigger, synchro information from the radar antenna and radar video information. The trigger is used internally to develop the radar sweep and range marks. Antenna synchro information is used to develop antenna rotation and angle marks information. The radar video is presented without modification. Results of these operations are applied in standard PPI form as a charge pattern on the memory surface of the TMA-403X video transformation tube.

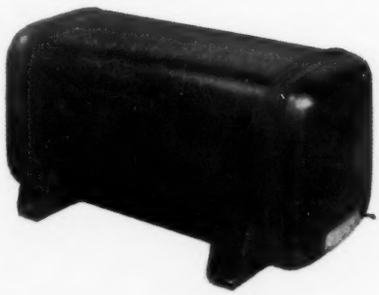
Read-out is accomplished as follows:

A master synchronizing generator, locked to the 60 cycle line frequency, develops the television timing signals for the horizontal and vertical triggers, horizontal and vertical blanking, and horizontal and vertical unblanking of the video transformation tube.

The reading beam of the tube is deflected in television raster form by the above-mentioned signals. TV video information is thereby generated at the target membrane of the video transformation tube. This information is collected and mixed with the necessary synchronizing and unblanking information to produce a composite TV signal.

In control room operation, scan conversion equipment will facilitate less fatiguing observation of displays and help to solve the increasingly complex air traffic problem.

Circle No. 179 on Inquiry Card

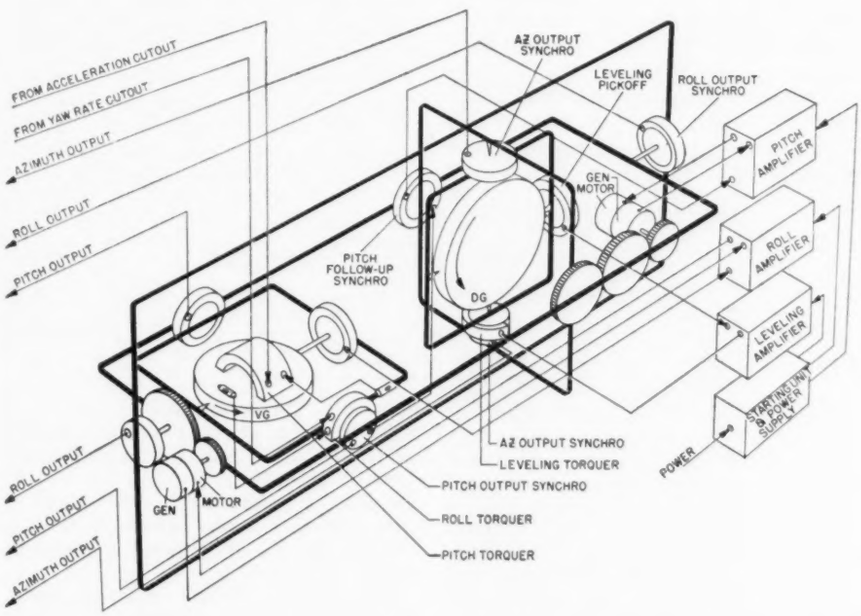


Lear Two-Gyro Master Reference provides precise stable signals simultaneously to flight indicators, automatic pilots, fire control systems, navigation systems and other instrument receptors. The package is designed to permit easy access for maintenance and adjustment of the miniature components.

AIRCRAFT INSTRUMENT

Two-Gyro Master Reference

A new two-gyro stable platform packaged in an envelope measuring 6½ x 6½ x 13 inches and weighing 19 pounds provides all-altitude reference signals to auto-pilot, attitude indicating, navigation, bombing, fire control and radar systems of advanced multi-Mach aircraft. Recently put into line production for use in both USAF and Navy jet aircraft, including the F-105, F-106, F4H and A4D, this new reference system developed by Lear, Incorporated, Grand Rapids, Mich. offers precision platform performance in a unit with minimum complexity. It is claimed to be the smallest, lightest and least expensive central master reference for high performance aircraft and to have an operating life in excess of 1000 hours without deviation from drift specifications.



Typical schematic of master reference for high-performance aircraft. The system combines a directional and a vertical gyro of high accuracy on a common no-gimbal-lock suspension. The directional gyro, which furnishes compass heading information, is a two-axis element stabilized by servo techniques in pitch and roll to eliminate the common and serious gimbaling errors that occur in conventional directional gyros during routine jet aircraft maneuvers. Random drift, the rate at which a directional gyro deviates from a fixed position in space, is extremely low. Completed performance tests on development instruments have shown drift rates of less than one degree per hour when magnetic heading control is removed. The vertical gyro has a dual function, providing non-tumbling roll and pitch (elevation) signals for flight instruments or for automatic control systems. The no-gimbal-lock design of the vertical gyro allows full freedom of that element throughout 360 degrees in either pitch or roll. The non-tumbling reference can provide accurate stabilization information during such maneuvers as the planned Immelman and the one-half Cuban Eight, both used in loft bombing, and during sustained near-vertical flight of advanced, high-performance aircraft.

Flight tests and laboratory qualification test programs have shown the great utility of a completely non-tumbling master reference. Since the new instrument serves as a master source of directional and vertical gyroscopic intelligence for all systems aboard the aircraft, it eliminates the necessity for individual gyros in each system with resultant savings in weight, space and cost.

Lear engineers claim the reference is one of the first aircraft instruments to be comprehensively tested under "random noise" type vibration, which includes all frequencies from 10 to 2,000 cycles per second at an average force of 10 times that of gravity, and under shocks of the same magnitude.

Development of the reference required a period of approximately four years, during which time all requirements of new aircraft of today's and tomorrow's vintage were studied. As a result, the new instrument is adapted, not only to currently projected production aircraft, but to aircraft now on the drawing board.

Circle No. 208 on Inquiry Card

Selenium, Silicon DC Power Supplies for Continuous Use

A new and complete line of testing units for guided missile and aircraft component power requirements, which features closely regulated continuous-duty d-c power supplies in either selenium or silicon, is now available from the American Rectifier Corporation. Known by their copyrighted trademark as SELENIFIERS, these magnetic amplifier-controlled (tubeless) rectifiers provide precise regulation of plus or minus 0.5 percent with less than 1 percent ripple factor in output. They have been engineered for continuous duty in all military and industrial applications. Large units have a cooling fan which is the only moving part of the rectifier. Push-button magnetic starter provides simplicity of operation: with input voltages of any range, three-phase, 50 or 60 cycles; with output ratings of 22 to 32 volts or better. *American Rectifier Corp., New York.*

Circle No. 105 on Inquiry Card

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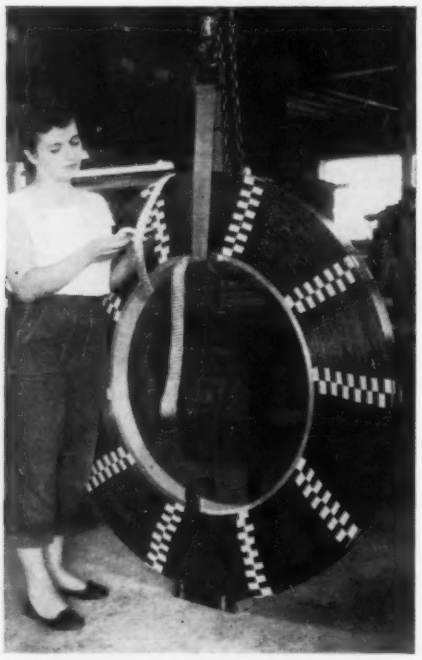

STONITE CUSTOM-MADE COILS COVER THE WIDEST SIZE RANGE —FROM THE TENTH OF A POUND TO A TON!

Here are two examples of this cycle, illustrating Stonite's versatility and manufacturing know-how.

Proven high-quality manufacturing materials, outstanding service facilities and prompt deliveries are of equal importance in Stonite's picture. For coils, mite to man size, you can depend on Stonite.

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CIRCLE 19 ON INQUIRY CARD

GEAR TRAIN ANALYZER

Constant-Torque Two-Phase Actuator Measures Lost Motion

A new gear train analyzer fulfills the need for a practical testing instrument to quickly and accurately evaluate lost motion in precision gear trains such as those used in servo units, computers, guided missiles, etc.

It is particularly adaptable to high ratio gear trains having small input torques, and is supplied complete with instructions and a manual on gear train design and analysis.

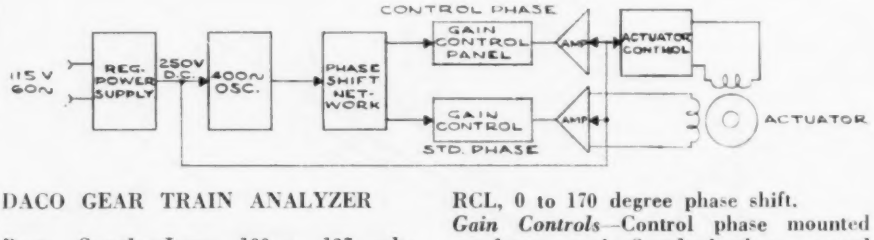
A production quality control instrument as well as a laboratory and engineering testing device, the gear train analyzer consists basically of an electronic control console and a two-phase torque actuator.

The torque actuator is substituted for the motor drive of the gear train to be checked. A dial on the control unit regulates voltage to the actuator, and a read-out dial on the actuator enables the inspector to determine angular displacement of the actuator shaft precisely during the test. Thus, total lost motion is measured by applying constant torque to the input pinion of the locked gear train and reading clockwise and counter-clockwise actuator shaft displacement.

Daco Gear Train Analyzer consists of an electronic control console to which is connected a torque actuator bearing a read-out dial calibrated in degrees to indicate angular displacement of actuator shaft during testing of locked gear train. Torque motors may be supplied from 2 oz down to 10 gram inches input. Special couplings and accessories for locking output shafts are supplied.

In addition to its standard function as a production inspection instrument, the analyzer measures torque required to drive free running gear boxes, facilitates adjustment of gear meshes and bearing alignments during assembly, and provides a means of setting gear train safety clutches. It also provides a practical method for testing gear trains under various environmental conditions. It operates on 115 volt, 60 cycle supply. Daco Instrument Co., Brooklyn 1, New York.

Circle No. 173 on Inquiry Card



DACO GEAR TRAIN ANALYZER

Power Supply—Input, 100 to 127 volts, 60 cycles, 150 watts. Tube compliment—5U4G rectifier, 6AS7 passing tube, 6SL7 regulating tube, 5651 grid regulating tube. Output, 250 volts, 200 mils d-c.
Oscillator—Tuning fork type frequency generator and 12AU7 output tube.
Phase Shift Network—Constant voltage, RCL, 0 to 170 degree phase shift.
Gain Controls—Control phase mounted on front panel. Standard phase control located internally.
Amplifiers—Input 12AX7, 2-6AQ5, push-pull. Matching output transformers.
Motor Control—Off, forward and reverse switch.
Torque Motor—Special calibrated motor for regulated torque output.

WORTH FILING

Vibration Mounting Systems

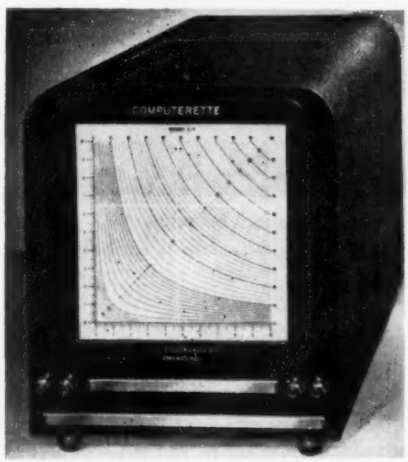
New 4-page bulletin describes engineered vibration and shock mounting systems for airborne electronic equipment and other applications. It cites the several different types of damage to sensitive instruments caused by vibration and shock. Descriptions and illustrations are given of variable-damped mounting systems, along with a detailed discussion of the design and selection of the component parts of these systems. A section deals with the problems encountered in vibration isolation mountings for gyroscopic instruments. Standard mounting bases; standard, miniature and subminiature unit mounts as well as special mounts are illustrated along with a listing of typical applications of these products.

Source: Federal Shock Mount Corp.
New York, New York
For your copy: Circle No. 219 on Inquiry Card

"Computerette"—A Computing Indicator

The "Computerette" is a unique electrical instrument that indicates a total of three quantities. Two of these are independent variables while the third can be any function of the first two. Thus, the Indicator is not only an indicating device but also a computer.

This instrument, intended for laboratory and industrial use, in combination with suitable transducers, can measure and indicate most physical quantities.



As one illustration, it can be used to indicate mechanical speed and torque as independent variables and show horsepower as the third, or derived quantity.

The indicator consists of two direct current reflecting galvanometers which, together with their associated optical systems, project light lines on to a ground glass screen located on the front of the instrument. These lines extend across the entire screen. One of them is horizontal and moves vertically a distance proportional to the galvanometer current. A scale along the left edge of the screen indicates the magnitude of this current or the desired quantity proportional to this current. The other line is vertical and moves in the horizontal direction a distance proportional to its galvanometer current. A scale located along the lower edge of the screen indicates magnitude of the galvanometer current or some quantity proportional to this current.

In addition to the two scales, the screen contains a family of curves representing the third quantity which is a function of the first two. The point where the two light lines intersect, together with the family of curves, indicates the third, or the derived quantity.

Since the family of curves shown on the screen can represent any mathematical or empirical quantity determined by the two quantities being directly measured, this indicator can be readily used to indicate quantities that can otherwise be determined only by laborious computation, or with the aid of complex and expensive computers.

The ground glass screen is readily removable and can be quickly replaced by one showing, for example, the ratio of the two measured quantities instead of their product, etc. Thus, the "Computerette" is not limited in its use to the indication of only one given computed quantity. This flexibility is of considerable value in engineering and laboratory test work.

For use in darkness, a general background light is provided for illuminating the screen as a whole. The intensity of illumination can be adjusted to suit the particular requirements. Aero Electronics Co., Chicago, Illinois.

Circle No. 174 on Inquiry Card

WORTH FILING

Servomotor Data

Four-page data sheet containing dimensional drawings, torque-speed curve, motor performance data of company's size 18 servomotor.

Source: Beckman Instruments, Inc.
Heliport Corporation
Newport Beach, California

For your copy: Circle No. 221 on Inquiry Card

Surveillance Rotary Switch

Rotary switch for sampling data from surveillance type radars, sonars and magnetometers has 3 poles, 16 nonshorting contacts per pole operating at reference frame voltage, and each of the other fifteen samples the returned response of a 25 degree cone. Leading edge of each contact on each pole is phased to less than 0.1 ms. Noise levels considerably less than 0.1 mv are available for 1.0 mv signal levels in a 50 ohm circuit. Unit is hermetically sealed and withstands MIL-E-8189 environmental conditions. Instrument Development Laboratories, Inc., Attleboro, Massachusetts.

Circle No. 194 on Inquiry Card

WORTH FILING

Electromechanical And Electronic Components And Systems

Forty-six-page brochure describing performance characteristics of electro-mechanical and electronic products and systems in the fields of power supplies, actuators, blowers, timing devices, and inverters as used in the manufacture of aircraft and missiles.

Source: Western Design & Mfg. Corp.
Goleta, California

For your copy: Circle No. 226 on Inquiry Card

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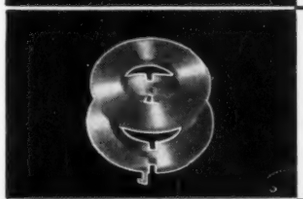
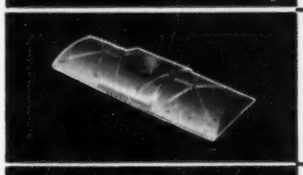
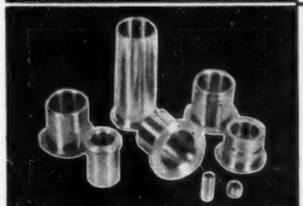
Industry is cutting costs through use of these SABECO BRONZE PRODUCTS. Countless applications! Check your needs.



SABECO SPLIT THRUST WASHERS
Efficiently take up end play in machine tools, cut repair bills and reduce downtime to a minimum by installing on equipment subjected to bearing thrust loads.



SABECO BRONZE SLIPPER SHOES
Slipper shoes of Sabeco Bronze render outstanding performance and service in many heavy duty applications in any practicable size to customers dimensions and specifications.



SABECO'S BEAUIDEAL STEEL-BACKED BRONZE BEARINGS
Steel and Sabeco Bronze bonded together forever. The strength of steel combined with the lightness of the bearing's bronze wearing surface makes Beauideal bearings especially adaptable to special applications under extreme bearing load conditions.

Write for Sabeco's bronze brochure giving data, specifications and applications. Dept. E-3

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SABECO INDUSTRIAL BRONZE BAR STOCK AND CASTINGS
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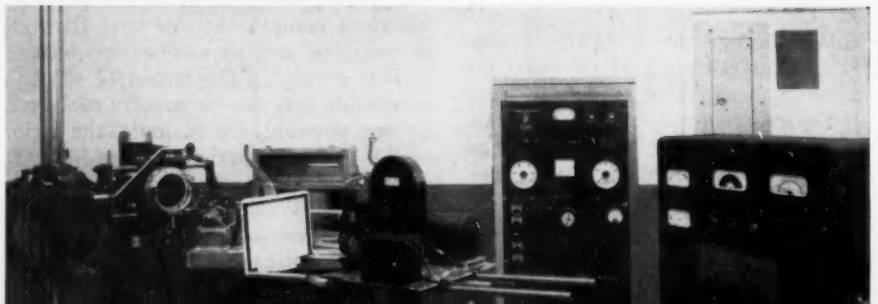
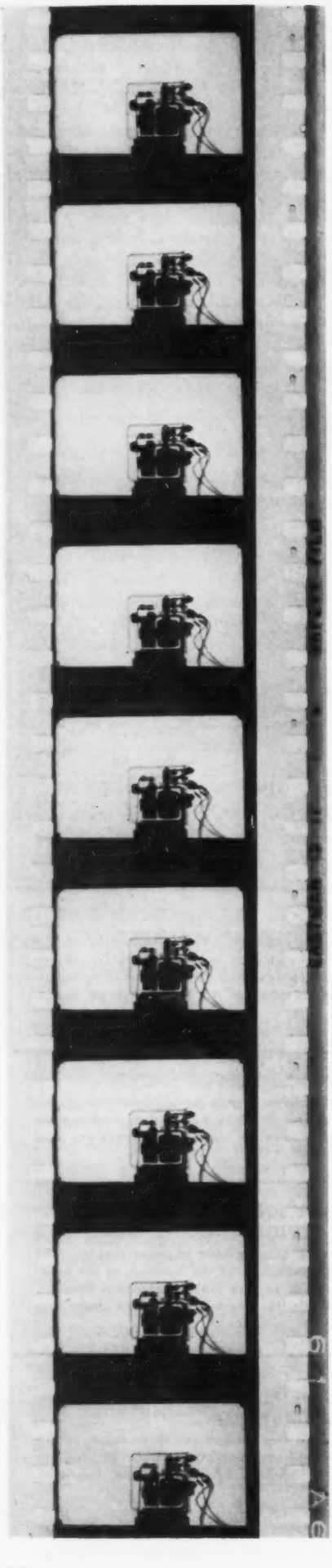
FOR MORE INFORMATION CIRCLE 20 ON INQUIRY CARD



X-ray motion picture facility at Rototest Laboratories.



DYNAMIC TESTING TIMESAVER

Filming a Failure with X-rays

As weapons systems become increasingly complex and chances for failure are multiplied, there is a growing effort to develop new test techniques not only for qualifying components but also to provide useful information on flaws and failures as an aid to redesign. Outstanding among new techniques for reliability testing of airborne components is the use of X-ray motion pictures or cine-radiography, a new dimension in non-destructive dynamic environmental testing.

The limitation of most reliability testing of components has been the inadequacy of quantitative results produced—reporting how many samples of a certain product will fail and after what periods of time. High speed X-ray motion pictures make it possible to show exactly what is happening in any portion of a component at any time during a qualification, to focus on a weak point when trouble appears and to present the failure as it occurs together with the condition accompanying failure.

Now test engineers are looking into heremetically sealed units such as relays and pulse-forming networks during dynamic testing. They are studying the failures of even the most minute sections of components as they are recorded on film with the aid of controlled penetration and laminography to focus at the critical point.

NOT A CURE-ALL

"Cine-radiography is not a cure-all for all reliability problems," states Rototest Laboratories' President, Joe Davidson, "but it is a unique approach to solving problems of component failures. It can provide a heretofore unavailable type of component performance data—pictorial evidence of the internal operation and failure of enclosed or sealed components. Utilizing cine-radiography, we can learn considerably more than just the fact that a component has failed. With proper technique, the causes of failure can be established almost immediately as failures occur. Where an unresolved failure has occurred and has been recorded, prints of the films can be studied by the engineers concerned. If necessary or desirable, engineers of both the manufacturer and user of the component can study the films simultaneously in order to accelerate the determination of the cause of failure and the subsequent redesign where necessary."

Cine-radiography is now being used in studying components and assemblies with moving parts, or components and assemblies with parts normally stationary but which may move under conditions of vibration shock or acceleration.

TIME-SAVING BIGGEST ADVANTAGE

Major advantages of the new technique:

- Saving time in isolating causes of failure
- Specifically identifying parts or materials which fail and exact time at which failure occurs
- Providing detailed visual evidence which may be studied repeatedly in engineering a unit redesign

• Over-all savings in both time and money in contributing to greater reliability of components

An electronic and electromechanical synchronization system keeps the motion picture shutter precisely in phase with X-ray pulses. The system is now being used at speeds of 20, 30, 60 and 120 frames per second. Rototest Labs, who have exclusive rights to the synchronizing system, say that much higher speeds, now under study, are feasible.

Size of objects which can be studied is a function of such variables as X-ray power available, speed of photography and materials to be penetrated. With a one-million volt X-ray machine, for example, a typical specimen with an area of four square feet might be photographed at 120 frames per second. A smaller component, such as an electric switch or hydraulic actuator, can be photographed at higher speeds using lower voltage rays.

A useful cine-radiography technique is the control of X-ray penetration to get sharp focus at various depths in an object. This is accomplished by varying the voltage and current in the X-ray machine as well as by rotating the X-ray machine and the motion picture camera while keeping the component under study and the fluorescent screen stationary. Lead shielding is used to examine in detail any portion or profile of the object being X-rayed.

At Rototest Labs, Lynwood, California, cine-radiography studies have been made showing the causes of failure during life, vibration and performance tests of hermetically sealed relays, switches, motors miniature amplifier tubes, tuners, timing mechanisms, potentiometers, potted transformers, and thermal relays.

Advances now being explored include the use of higher kilovoltage X-ray machines, the practical use of higher speed photography, use of laminography, the correlations of X-ray motion pictures with other media such as oscillographs and with closed circuit television techniques, and the development of portable units for use in flight.

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WORTH FILING

Printed Circuits

W-29 Text:
Brochure on printed circuitry in file folder style contains full descriptive data on materials, specifications, design tolerances, and application information.

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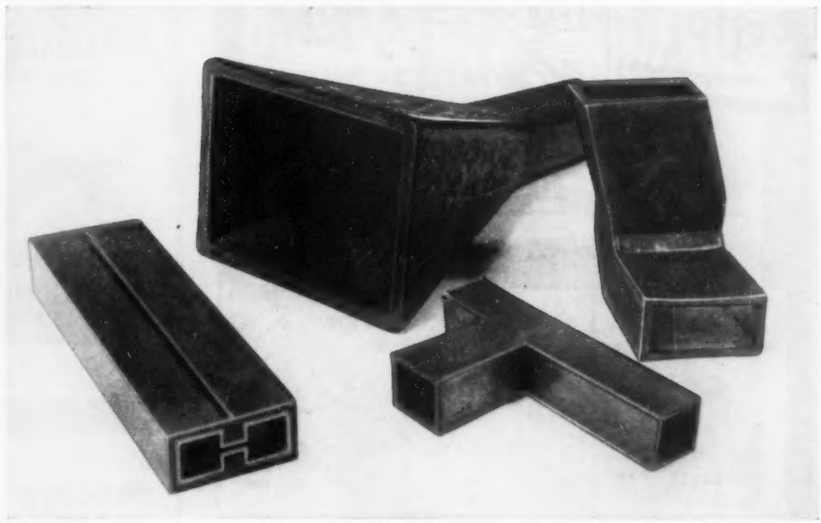
Electroforming



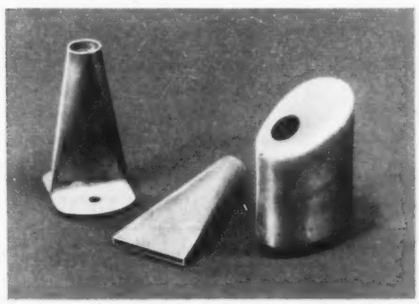
Laminates of metal to metal can be produced in various thicknesses by depositing one metal over another.

New Latitude in Design

Improvements in electroforming, a relatively new production technique, now permit this process to be applied to the production of high precision electro-mechanical components. It is now used in the production of metal shapes, especially those of tubular, conical or cup-like parts, more economically than by deep-drawing or other operations involving more than a simple swedging or stamping.

Basically the electroforming process involves the electrodeposition of a layer of metal on a master mandrel and the subsequent removal of the plated shell so that a self-supporting part or formed article, not a mere coating, is produced. In forming complicated shapes that involve undercuts, the mandrels are made of low melting alloys that can be melted out in a hot oil bath. Electroformed interior surfaces achieve highly reflective mirror finishes without polishing and produce an extremely high degree of density without porosity.

High precision parts are now being electroformed from nickel, copper, iron, silver, lead, tin, cadmium, zinc, cobalt, indium, and chromium.



Instrument float made in one piece with a wall thickness of 0.005" eliminates the need for any welding or soldering operations normally used in joining halves.

Left: Pendulum for gyroscope concentric within 0.001".

Right: Magnetron cathode support made of high-purity electrolytic nickel.

Feel free to send us prints or samples for our engineering comment and quotation. No obligation or charge, of course.

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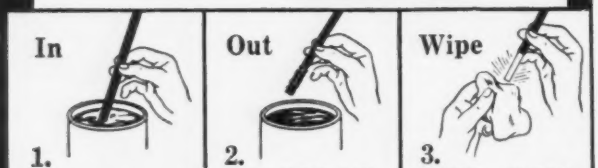

1. DIP WIRE in SUPER X-VAR for 3 seconds.

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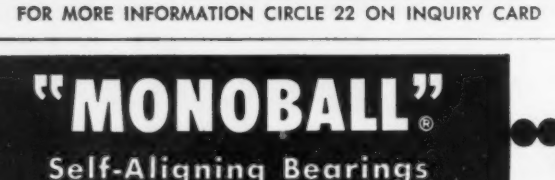

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2	Chrome Moly Steel Ball and Race	For types operating under high radial ultimate loads (3000-893,000 lbs.).
3	Bronze Race and Chrome Moly Steel Ball	For types operating under normal loads with minimum friction requirements.

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NEW TECHNIQUES

MATERIALS PROGRESS REPORT

STAFF COLUMNIST
David Bandel
Associate Technical Director,
TRACERLAB, INC.

TRACING AND CHASING WITH RADIOISOTOPES

Radioisotopes are a natural for tracing applications. Numerous difficult tracing problems have been solved rapidly and simply by using a properly selected source of activity and detection system for the particular problem under consideration. Several recent applications and proposed applications may be of interest in the electromechanical field.

Splice Detection

In many processes, splicing is unavoidable but the spliced sections must later be removed at some point down the line. One problem of splice detection was solved readily by the proper choice of radioisotope and detection set up. This involved a wire splice that was subsequently covered by extruded insulation. The splice had to be detected and removed on the fabrication line to prevent incorporation of the splice in the fabricated unit. Since the interval between splicing and fabrication of the unit was short, several days at most, a short lived radioisotope, phosphorus-32, was a natural choice for this application. Phosphorus-32 has a half life of 14.5 days and emits only beta radiation. Beta rays have relatively low penetrating power so that shielding is quite simple; 0.25-0.50 inches of Lucite would be adequate for beta radiation of the 1.7 Mev level emitted by P-32. The short half life results in rapid decay of the small amount of activity used initially to an insignificant level, eliminating all possibility of build-up of significant levels of radiation. In practice a fraction of a microcurie of activity is used for each splice so that the radiation intensity even at close range is negligible.

Actual location of the splice is accomplished with standard radiation detection equipment. The specific system used depends upon the residence time of the wire in the detector head range, radiation flux and the required reliability of detection. In the wire splice case above a standard ratemeter was modified to energize a relay when activity was detected. The relay arm had a knife blade attached to nick the insulation of the wire. Subsequent passage of the wire through a hi-pot testing head used for routine inspection of the wire showed up the splice as an insulation defect.

Similar systems can be used quite readily for splice detection in electrical and mechanical operations. In the capacitor field, metal foils and dielectric films could be

tagged at the splices and the units having a spliced section spotted and removed without shutting down the capacitor winding machines. Welds can also be tagged by the use of appropriate radioisotope tags. The simplicity and reliability of radioisotope tracing techniques makes them extremely adaptable to this type of production line monitoring.

Chasing

Chasing is another form of radioisotope tracing. The penetrating ability of radiation makes solid material transparent for many purposes. The exact location of line blockage is an illustration of chasing techniques. The principle is quite simple. A radioactive source is moved along the line until the point of blockage is reached. A simple radiation detector then pinpoints the exact point of blockage. The method of moving the source along the line frequently requires some ingenuity. Chasing has been used to locate cylinders stuck in pneumatic tube systems. A cylinder containing a small quantity of cobalt-60 was sent up the pneumatic tube. A portable battery operated radiation survey meter was used as the "sniffer" to locate the blockage. This was an extremely simple task since the radioactive source could be moved along the line without any difficulty. In many cases moving the source along the line could offer considerable difficulty.

Chasing techniques are now used routinely by pipeline transmission engineers to locate obstructions in pipelines. Obstructions located to date include a dead jack rabbit and several wiping rags.

In some instances the source is initially fixed in position and is subsequently moved by some action that is to be detected and recorded. This technique can be used to determine when erosion or abrasion in closed systems has proceeded to a given depth. The erosion of furnace linings has been monitored by this method. A radioactive source with the proper characteristics, cobalt-60 in this case, is embedded in the brick lining of the furnace at selected depths. The number of sources used per course of brick depends upon the geometry of the system. In a blast furnace that is cylindrical, 3 sources per course spaced 120° has been used. The location of each source and the course in which it is embedded is noted. Periodic checks of the presence of activity at these locations will reveal immediately whether erosion of the brick has reached the depth of the embedded sources. By suitable refinement of this procedure abrasion and corrosion in many closed systems can be detected and measured where previous types of inspection have been impractical.

Tracing and chasing techniques have been applied to the solution of more sophisticated problems. In petroleum refineries the rate of turnover of catalyst in a fluidized bed monitored by the frequency with which a radioactive tracer passes a detector station. The linear rate of flow is also measured by timing the passage of the source between 2 fixed detector stations. By the addition of a density measuring head the mass rate of flow can be determined. The velocity profile of shells along a gun barrel can be determined by embedding a radioactive source in the shell and timing its passage along the length of the barrel. It should be possible to design remote indicating inertia free tachometers free of mechanical and optical limitations. Many difficult problems in displacement and frequency of cyclic motion can be solved simply and unequivocally by the use of radioisotope tracing. Someone in the lab here has quipped "Have source—will travel". When a source travels it is easy to find out just where it has traveled to. This is one of the keys to the solution of some tough problems. END

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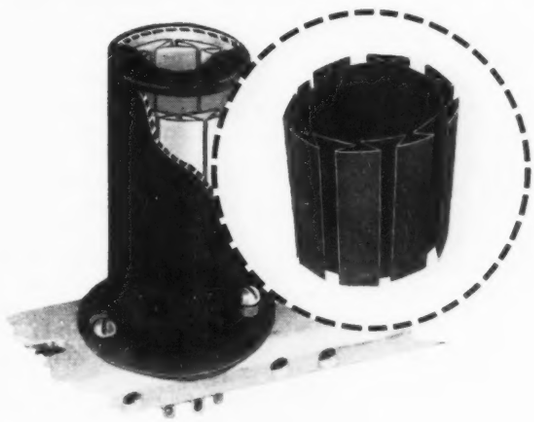

- *Insert makes almost 100 per cent contact with tube envelope*
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FOR MORE INFORMATION CIRCLE 24 ON INQUIRY CARD

FLOWSOLDER

New system of soldering printed circuits

Dip-soldering of printed circuits presents special problems:

• Only the underside of the panel should come in contact with the molten solder. This requirement necessitates flat dipping which is inherently more difficult than complete immersion.

• Dipping temperature and time must be reduced to a minimum to prevent heat damage to plastic panels and components mounted on the panels. This requirement restricts choice of solder to an alloy with as low a melting point as possible.

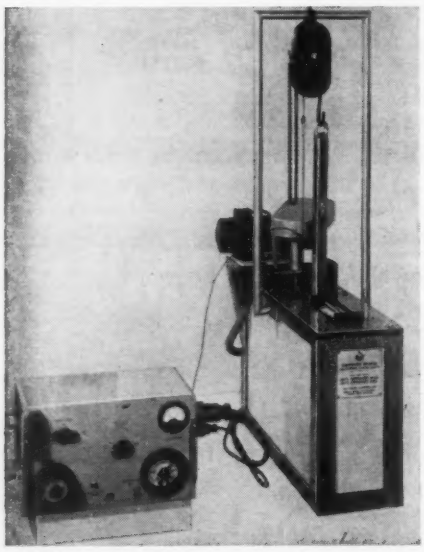

FIG. 1—"Flowsolder" equipment set up for printed circuits.

These problems led to development of the "Flowsolder" unit which forces the metal upwards by an impeller pump through an elongated nozzle so that it forms a stationary smooth surfaced wave. The circuit panel is passed through the crest of this wave of molten solder to solder the joints between the component leads and the copper conductors on the underside of the panel.

The manufacturer reports the "Flowsolder" system offers the following advantages over those of conventional dip-soldering methods:

• Automatic angled entry and exit. The Flowsolder unit automatically provides angled entry and exit by the shape of the solder wave. This characteristic, together with the washing action of the moving solder, prevents trapping of flux or air and assures sound joints.

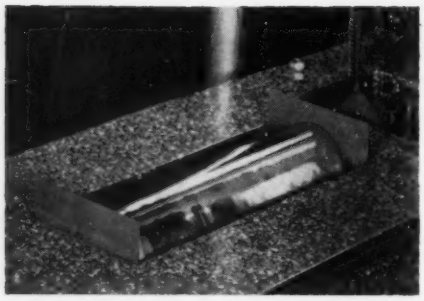

FIG. 2.—Close up of molten solder wave.

• Handles panels of any length. Flat-dipping is not suitable for long panels sometimes used for special assemblies —the new system, with its 8 inch nozzle, handles panels up to 7½ inches wide and up to any practical length.

• Simple conveying system. Panels move along a straight path preventing hesitation or break in the production flow and providing real automation in the operation.

• Perfect soldering. Panel passes through a wave of constantly flowing solder providing a more rapid heat transfer from solder to panel which reduces dipping time and controlled temperature assures consistently sound joints. Surplus solder drains back into the bath so that it does not form icicles or bridges between adjacent conduits. The solder is always on the move at the right temperature, eliminating surface chilling.

• Short panel exposure to heat. Only a 2 inch wide strip of the panel is in contact with molten solder at any given time, thus reducing warping of the panel and heat damage to components.

• Continuous flow of clean solder; no skimming is necessary. Molten solder welling up through the nozzle is drawn from below the bath surface and is therefore always clean and free from oxide or dross.

• Accurately controlled wave level. Elaborate level control to close limits is not necessary because height of the wave is easily regulated by adjusting speed of the pump. Level of bath is kept constant within convenient limits by a float controlled automatic ingot feeder which lowers a specially shaped feeder ingot into the bath to provide a constant supply of pre-heated solder and avoid temperature fluctuations which would arise from adding fresh metal at intervals.

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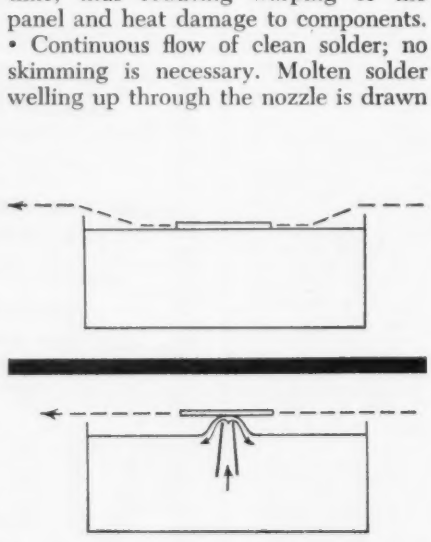


FIG. 3.—Upper panel illustrates curved path panel takes across solder surface. Lower panel illustrates straight path of panel through the solder wave.

UPPING MOTOR LIFE

Rhodium-plating of commutators reduces static, wear and current requirements

The electric fuel pump motor of an interceptor plane was causing manufacturing delays because it would not deliver enough fuel when drawing the maximum allowable current. Investigation revealed that rapid formation of a copper oxide film on the commutator segments increased contact resistance, to cause arcing, excessive brush wear, a high working temperature and a greater power load on the aircraft. Also, after as little as 120 or 130 hours, commutator wear was noticeable.

To find a way of avoiding these losses, commutators of one motor were rhodium-plated but not those of a duplicate control sample. Commutators in this test were 1.25 inch in diameter and had 24 copper segments, each 0.75 inch long with a 0.025 inch gap between adjacent bars. Thickness of rhodium deposit was 0.00005 inch although later trials revealed that half this amount would have been enough.

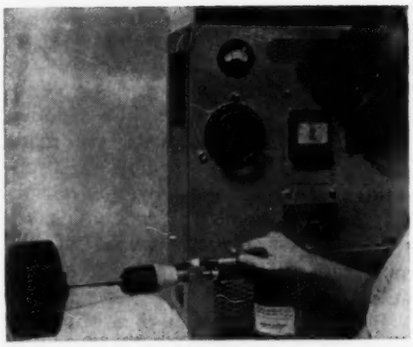
Improvements in performance were noted at once. Table I shows representative test results. After 385 hours of continuous operation, armature current under load is up to 12 percent less for each pump with a rhodium-plated commutator.

Some unexpected side-benefits were also discovered.

• Temperature of the plated commutators was 240 degrees C (464 F) as against 300 degrees C (572 F) for the unplated commutator.

• Wear was reduced from a former value of 0.030 inch after 168 hours to no measurable wear after 600 hours for the plated commutator.

• Radio interference was eliminated.



Only one major piece of equipment is needed for Dalic plating: a special rectifier with a finely graduated voltage regulator, permitting close control of plating current. A lead from the rectifier, the cathode, is clamped to a small lathe in which the armature is rotated. The other lead has a special plating stylus fitted with a pure graphite anode. The latter is wrapped in cotton and dipped in the proper plating solution. With current on (output voltage for this application is 12 v d-c), the wet anode is swabbed over the area to be plated and immediately highly cohesive, non-porous deposits of metal are obtained. Thickness of deposit depends directly on plating time and current, indicated precisely by a finely graduated ampere-hour meter on the rectifier. Deposits of any reasonable thickness may be obtained with an accuracy of ±5 percent.

Formerly interference had meant removal of a rotary converter from aircraft after about 300 hours. A rhodium-plated armature allows the same unit to stay in static-free operation for several thousand hours.

In one respect elimination of wear was actually a disadvantage because it took longer to seat the carbon brushes properly—60 hours instead of the usual 20. This problem was solved by bedding in the brushes before plating the commutator segments.

To be certain that use of the plating solution would not harm the windings, two plated armatures were immersed in the rhodium electrolyte, then hung up in the test house. After three months, windings and core were undamaged; the armatures placed into operation without prior servicing functioned smoothly.

The Dalic plating process used in these tests is claimed by its originators to be particularly advantageous for this application because it is fast and inexpensive and because the commutator may be treated without immersing the entire armature in the corrosive plating solution.

TABLE I

Comparative Test Results, Plated vs Unplated Commutators

Maximum Current Allowable: 25 amp

	Amperage at start of test	Amperage after 300 hours
Motor 1		
Unplated	23.0	25.9
Plated	23.0	22.8*
Motor 2		
Unplated	23.0	26.0
Plated	23.0	22.8*
Motor 3		
Unplated	23.0	26.0
Plated	23.0	23.5*
Motor 4		
Unplated	23.0	25.9
Plated	23.0	23.6*

*These values were essentially the same after 600 hours of continuous operation.

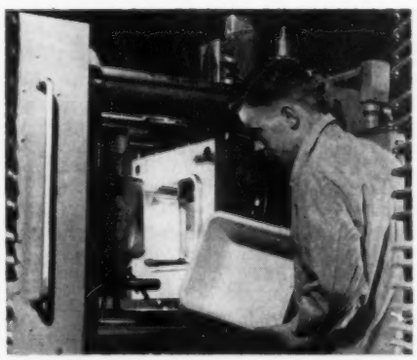
Circle No. 182 on Inquiry Card

Valve-Gate Molding

A new plastic injection molding technique can save a large percent of manufacturing costs for a wide variety of consumer and industrial products.

Normally, injection molding is carried out when the molten material begins to ooze through an opening into the mold cavity. The new valve gate technique holds the material in a reservoir, building up pressure that releases the valve and causes the material to gush into the cavity at high velocity. One of the advantages of the new method is that it permits multiple valve gating which enables the molding of larger and deeper pieces with greater areas using considerably smaller machines. In some cases, valve gating will make it possible to mold a piece which could not otherwise be molded, regardless of press size.

The valve gating technique has been used by Columbus Plastics Products in



production runs using various thermoplastic materials. Grace's Polymer Chemicals Division, as a result of extensive work in its own laboratories with Grex high density polyethylene, predicts that the new technique will revolutionize not only molding of high density polyethylene, but molding of all thermoplastic materials.

Continued on page 44

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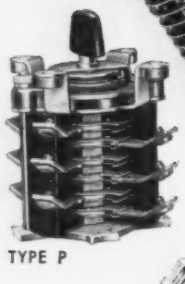
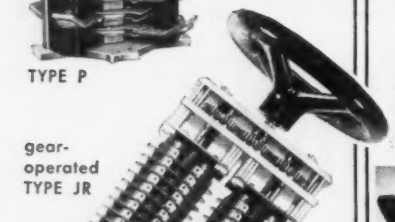
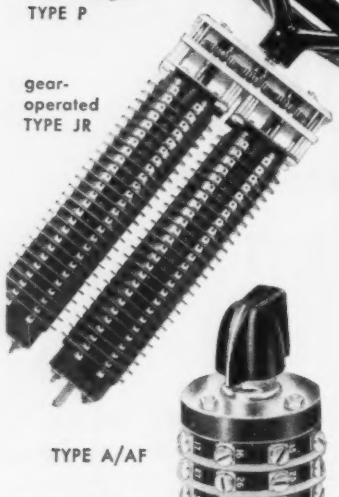


TYPE JR

TYPE P

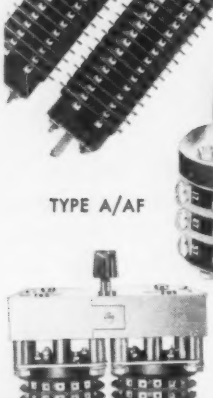


gear-operated TYPE JR



TYPE A/AF

geared pair TYPE HT



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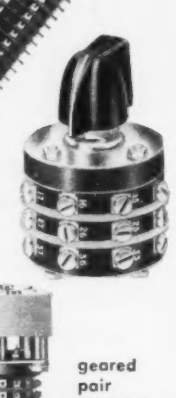

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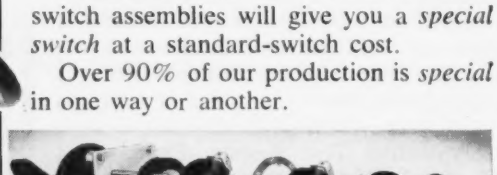

These standard switches can be modified to fit your application:

- *Type A* — up to 8 positions, 7 sections maximum, detent mechanism, rating 5 amp. 125 volts a-c/30 volts d-c.
- *Type AF* — up to 8 positions, 6 sections maximum, detent action, rating with resistive load 5 amp. at 28 volts d-c or 115 volts 400 cps, per MIL-S-6807.
- *Type P* — Multi-section, up to 4 positions, snap-action, rating 10 amp. 125 volts a-c, 5 amp. 125 volts d-c, 30, 60, 100, 200 amp. 500 volts a-c, or 250 volts d-c. Can be assembled to meet Specification MIL-S-15291.
- *Type JR* — up to 8 positions, 30 sections maximum, detent action, rating 10 amp. 125 volts a-c, 5 amp. 125 volts d-c.
- *Type JD-JS* — up to 8 positions, 5 sections maximum, detent action or snap action, rating 30 amp. 230 volts a-c.
- *Type HT* — up to 16 positions, 10 sections maximum, detent action, rating 5 amp. 125 volts a-c.
- *Geared-Pair Type HT* — up to 16 positions, 20 sections maximum, detent action, rating 5 amp. 125 volts a-c. A single knob controls two Type HT switches assembled with a gear mechanism.
- *Navy Switches* — to MIL-S-15291 and Bureau of Ships drawings 9000-S6202-73075, 73826, 73827, 73295, 74422, and others.

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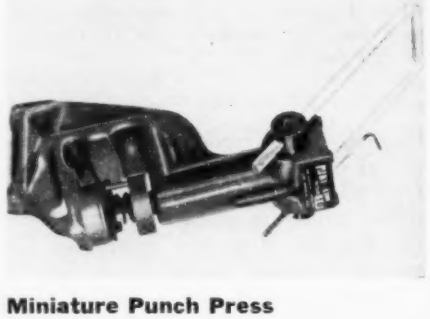
FOR MORE INFORMATION CIRCLE 26 ON INQUIRY CARD

Grace engineers say that the greater economy of operation results from reduced molding cycles, considerably decreased scrap and rejects, as well as less finishing costs. They also say that highly improved products are made possible through better physical properties and reduction of over-all shrinkage, and that further economies are realized by reduced weight of the molded part and a higher degree of automatic molding.

Basic plastics engineering principles apply to valve gating methods as in other methods.

This "pre-compression" method, known as valve gating, was developed and patented by Columbus Plastic Products, Inc., who has granted an exclusive license to W. R. Grace & Co.'s Polymer Chemicals Division, Clifton, N.J. Grace, in turn, is responsible for arranging licenses, involving royalty payments to Columbus, for plastic molders who wish to take advantage of the new technique.

Circle No. 175 on Inquiry Card



Miniature Punch Press

Designed for instrument work, fine punching, staking or forming operations, this miniature press is useful in laboratories, research and development work and for short run production jobs. Typical uses are for eyeletting terminals on printed circuits and terminal boards, pressing in bearings and pins, and riveting. Its close fitting ram provides absolute accuracy of alignment, extremely important on repeat operations, particularly on very small parts. The unit is 7 inches high and weighs 3.5 pounds.

Magnetic Corporation, Los Angeles, California.
Circle No. 236 on Inquiry Card

WORTH FILING

Industrial Fasteners

Eight-page catalog describing standard and special types of die cast and molded nylon fasteners, bushings, screws, and set screws.

Source: Gries Reproducer Corp.
New Rochelle, New York
For your copy: Circle No. 222 on Inquiry Card

MATERIALS

DUCTILE BISMUTH

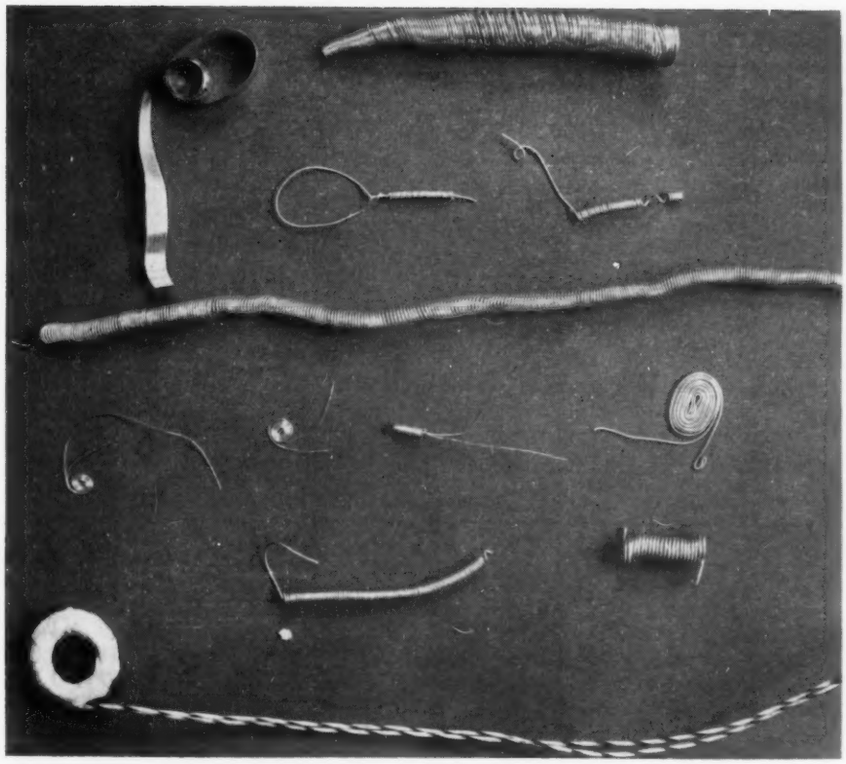
New Process Eases Applications

Bismuth, the last stable metal in the atomic scale, is an extremist's metal; any way you analyze it, it is either the best or the poorest. Because of its useful electrical properties, it has been used for thermocouples, grids, resistance controlled circuits, variable resistors, and gauss meters, but its brittleness, weakness, lack of ductility, and poor soldering characteristics have caused application problems galore. Now Fitzpatrick Electric Supply Co. in Muskegon, Michigan, has come up with a process for increasing the ductility of bismuth and thereby considerably decreasing problems in its application to electromechanical designs.

Here are some of bismuth's extreme properties, normally considered useful: • Most diamagnetic of all metals • Highest Hall coefficient for ductile metals • Greatest resistance change in a magnetic field • Greatest resistance of pure ductile metals per mil foot • Greatest resistance change with temperature of all ductile metals • Lowest thermal capacity of all metals, which makes it a most ideal metal for thermocouples where rapid response is required • Least thermal conductivity of all pure ductile metals • Highest negative thermocouple voltage per degree change in temperature • Most rapid thermocouple response to temperature change.

The other side of the picture is just as extreme: Melts at 520 degrees F, goes into solution with most metals and starts attacking at melting point. In addition, its alloys lower the melting point, making it hard to solder; it is very brittle, very weak, has large crystals, work hardens rapidly and starts oxidizing at 300 degrees F.

Fitzpatrick Electric Supply Company has succeeded in making bismuth more ductile than has been attained by any other known processes. However, it is not as ductile as copper or gold; but ductile enough to make a usable wire although that wire cannot be deformed, as a copper wire can be flattened, and still retain its ductility. The bismuth wire crystallizes; its tensile strength is still low—1500 psi. If used with the above considerations, you can make any kind of coil. Fitzpatrick now makes chemically pure bismuth wire in sizes from No. 37-36-35-34-33 and 29, in both insulated and bare form. They also use 0.05 of 1 percent nickel alloyed with bismuth to gain increased tensile strength. This amount of nickel does not detract from its gauss response and is stronger.



TYPICAL FORMS MADE WITH DUCTILE BISMUTH

THERMOCOUPLE APPLICATIONS

For thermocouple application the negative wire is an alloy of bismuth and nickel using 0.17 of 1 percent nickel, the balance of bismuth of 99.9992 purity. The positive leg is an alloy of tin and antimony. These legs make a thermocouple for the low temperature ranges of minus 118 F to plus 350 F with an output of 0.03944 milliamperes per degree F which has not only straight line performance but also by far the largest output per degree of any existing thermocouple in any temperature range.

RESISTANCE CONTROLLED CIRCUITS

The high basic resistance of bismuth, 720 ohms per mil foot, can be radically changed by temperature and by a magnetic field. One ohm at zero C or 32 degrees F can become only 0.4 of an ohm at minus 192 C or 1.79 ohms at plus 183 C. Bismuth has the greatest resistance change of all ductile metals subjected to temperature changes. The following table is a comparative valuation of bismuth for use in resistance bridges. The important factor for such use is the product of resistance times the temperature coefficient, designated as "K" in the table.

Metal	Resistivity ohm-cm 20° C	Temp. Coef.	K
Bismuth	120	0.004	0.48
Copper	1.72	0.0039	0.0067
Climax	87	0.0007	0.061
Nichrome	100	0.0004	0.040
Nickel	7.8	0.006	0.0468
Platinum	10	0.003	0.03
Tantalum	15.5	0.0031	0.0480
Tungsten (drawn)	5.6	0.0045	0.025

The combination of high resistance multiplied by its temperature coefficient makes bismuth over eight times more efficient than its nearest alloy or metal, and over seventy times that of copper for this type of application.

The change of resistance by a magnetic field in bismuth is the greatest of all usable metals, alloys, or compounds. It varies from 88 times at minus 192 C to 3 times its original resistance at plus 18 C or from zero to 35000 gausses. Also, at any constant temperature, bismuth will give a straight line from 2000 to 35000 gausses. But as previously mentioned, the lower the temperature the greater the amplifying factor.

Therefore, bismuth is a natural in all types of resistance controlled circuits either by magnetic field or temperature or a combination of both.

H gauss	500 ohms element	1000 ohms element	2000 ohms element
0	500	1000	2000
2000	513.89	1027.78	2055.56
4000	560.19	1120.37	2240.74
6000	611.11	1222.22	2444.44
8000	657.41	1314.81	2629.63
10000	712.96	1425.93	2851.85
12000	773.15	1546.30	3092.60
14000	833.34	1666.67	3333.34
16000	893.52	1787.04	3574.07
18000	953.70	1907.41	3814.81
20000	1018.52	2037.04	4074.07
25000	1166.67	2333.34	4666.67
30000	1324.07	2648.15	5296.30
35000	1504.63	3009.26	6018.52

Table II. Resistance change for bismuth at room temperature (18 C).

H gauss	−192°C	−135°C	−100°C	−37°C	0°C	18°C	60°C	100°C	183°C
0	0.40	0.60	0.70	0.88	1.00	1.08	1.25	1.42	1.79
2000	1.16	0.87	0.86	0.96	1.08	1.11	1.26	1.43	1.80
4000	2.32	1.35	1.20	1.10	1.18	1.21	1.31	1.46	1.82
6000	4.00	2.06	1.60	1.29	1.30	1.32	1.39	1.51	1.85
8000	5.90	2.88	2.00	1.50	1.43	1.42	1.46	1.57	1.87
10000	8.60	3.80	2.43	1.72	1.57	1.54	1.54	1.62	1.89
12000	10.8	4.76	2.93	1.94	1.71	1.67	1.62	1.67	1.92
14000	12.9	5.82	3.50	2.16	1.87	1.80	1.70	1.73	1.94
16000	15.2	6.95	4.11	2.38	2.02	1.93	1.79	1.80	1.96
18000	17.5	8.15	4.76	2.60	2.18	2.06	1.88	1.87	1.99
20000	19.8	9.50	5.40	2.81	2.33	2.20	1.97	1.95	2.03
25000	25.5	13.3	7.30	3.50	2.73	2.52	2.22	2.10	2.09
30000	30.7	18.2	9.8	4.20	3.17	2.86	2.46	2.28	2.17
35000	35.5	20.35	12.2	4.95	3.62	3.25	2.69	2.45	2.25

Table III. Gauss change at several temperatures for bismuth. Resistance at O C and H=O is taken as 1.0 ohm.

Bismuth can be used as a gauss meter to control the gausses applied to coils; as an automatic control, a variable resistance with no moving parts and no contacts that generate noises; a voltage regulator; and many other applications where the change of resistance is required. Its very high resistance allows a large resistance in a small space. All the above can be accomplished by moving bismuth into the field or the field into the bismuth. The resistance of bismuth changes with an alternating current up to 480 cycles per second with no perceptible lag.

Fitzpatrick makes three sizes of bismuth grids with different working surfaces that take up to 120 volts at one milliampere.

HALL EFFECT APPLICATIONS

The Hall Effect, relating changes in potential with magnetic field strength, is E=ih/d where

E=transverse potential difference
i=current (longitudinal)
d=thickness of the strip
h=magnetic field strength

Thus, d has to be as thin as possible to have E become as large as possible. To meet this need Fitzpatrick developed a bismuth foil ¼ inch x 0.0055 inch thick in lengths up to 70 feet.

They also developed bismuth films mounted on a plastic strip with a working surface of 5/16 inch x ¾ inch; all four leads are carried to one end of the plastic strip. The center taps are as near the unipotentional point as possible, but is not 100 percent correct. Therefore, there is a small difference in potentional when the current is reversed, an error which has to be accounted for. Their engineers hope to eliminate this difference in the near future.

Data on bismuth applications that utilize the Hall Effect are very sketchy because of the lack of a consistent film; results of experiment are questionable upon duplication.

But Fitzpatrick claims that they can measure an 0.07 gauss field with a 1.5 microvolt result. This sensitivity is desirable when one remembers that the earth's magnetic lines of force are between ¾ to ¼ gausses.

They report that an 0.0008 inch film carrying 50 milliamperes d-c current in a field of 100 gausses had an output of 269.5 microvolts with good linearity to 5 microamperes with an output of 0.032 microvolt.

In another group of tests a d-c current of 100 milliamperes through a field of 10,000 gausses had an output of:

Film	Output
1μ thick	42 millivolts
0.5μ thick	74 millivolts
0.33μ thick	102 millivolts
0.25μ thick	135 millivolts

The films used in these tests were not typical production films but were developed for research purposes. Fitzpatrick expects many new and novel uses of bismuth when its availability and usefulness become more generally known.

Circle No. 158 on Reader Inquiry Card

New Alloy For Heating Elements

A new series of iron-chromium-aluminum electrical resistance alloys are said to offer improved physical and mechanical properties, and to be completely free of all critical raw materials.

Known as Alloy 875, the new material was developed primarly for use as heating elements in industrial furnaces, kilns and other types of heating equipment where maximum continuous operating tmperatures up to 2350 degrees F are required.

Improved properties of the new alloy include excellent resistance to oxidation at high temperatures, high electrical resistivity (875 ohms per circular mil foot at 68 degrees F), and a low specific gravity (7.10). It is also reported to have improved uniformity and ductility over other iron-chromium-aluminum alloys and to show less susceptibility to growth and distortion, and to increase in resistance at high temperatures. Hoskins Mfg. Co., Detroit, Michigan.

Circle No. 214 on Inquiry Card

New Liquid Epoxy Resins

The Dow Chemical Company has entered the liquid epoxy resin field with three basic resins. D.E.R. 332 is said to be unique in that it is water clear, extremely uniform, and has very low viscosity—characteristics previously unattained in the epoxy field. D.E.R. 331 is a standard unmodified resin suitable for customary use in tooling, casting, adhesives, and electrical encapsulating. D.E.R. 334 is a modified low viscosity resin said to be especially suited for laminating. The company is conducting extensive research in other epoxy formulations.

Circle No. 218 on Inquiry Card

MATERIALS

Lathe Cut Rings

Lathe-cut synthetic-rubber rectangular-cross-section rings for sealing applications are now available in all the various compounds from which Parker o-rings are molded. A new process economically produces "flat" rings to dimensional accuracy within closer tolerances than ordinary lathe cutting, making the rings suitable for many gasket applications. Parker Rubber Division, Parker-Hannifin Corp., Cleveland, Ohio.

Circle No. 215 on Inquiry Card

Corrosive Resistant Coating

A new lining material, called Vyflex Fligid, makes it possible to line large areas with a minimum of installation problems in protecting them from corrosive elements. It is said to protect base materials of both ferrous and nonferrous metals, concrete as well as wood. It resists a broad line of corrosive chemicals, ranging from concentrated oxidizing acids to highly concentrated alkalies, as well as a large number of corrosive organic chemicals. Produced in continuous sheets, the lining material consists of unplasticized polyvinyl chloride, which lends itself to chemical bonding to the base materials. It is secured to the base material with a cementing system that bonds with an average of 25 pounds per linear inch peel strength. Joints between individual panels or sections of the lining are hot-gas-welded with an unplasticized polyvinyl chloride filler rod or strip to assure a homogenuous surface. Equipment Division of Wagner Brothers, Inc., Detroit, Michigan.

Circle No. 216 on Inquiry Card

Conductive Adhesives

New conductive adhesives have been developed for use where soldering is impractical. Called Eccobond, these epoxide based materials in paste form can be cured rapidly at moderate temperatures to produce rigid solids with low electrical resistance. Adhesion is excellent to metals, plastics, glass and ceramics. Bond strength is above 2000 psi. Conductivity of resultant compositions compares with that of metals. No solvent is present. Once cured, these materials can be used from −65 degrees F to +500 degrees F. They have excellent thermal conductivity, can be thinned out and applied as surface coatings, and require no mixing. Emerson & Cuming, Inc., Canton, Mass.

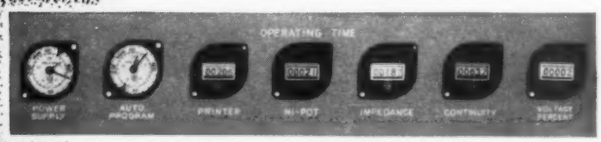
Circle No. 232 on Inquiry Card

SPACE IS Valuable

... So Use the A. W. HAYDON company's

SUB-MINIATURE HERMETIC ELAPSED TIME INDICATORS.

You, too, can afford the space to keep track of time! From now on, these really small (1¼") Elapsed Time Indicators will keep company with the best of Electronic Miracles.



The illustration shows how the operating time of various sections of an electronic console can be monitored.

The dial type units read up to 2,500 hours in one hour increments, while the digital type units read up to 9999.9 hours in one-tenth hour increments. Designed for military applications, these 4½ ounce units can save valuable panel space in industrial and electronic applications.

The 400 cycle models now in production are described in Bulletin AWH ET 602.

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Faster cycles—Redheads recover up to 5 times faster.

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Exclusive construction — Highest quality nickel-chromium resistor wire coiled around special ceramic core, centered in refractory material with highest heat transfer ability. Inconel sheath combines fast heat transfer with resistance to high temperature corrosion. Flexible lead wires of standard manganese-nickel are covered with special high temperature insulation.

85 to 4600 watts . . . 120-240 volts
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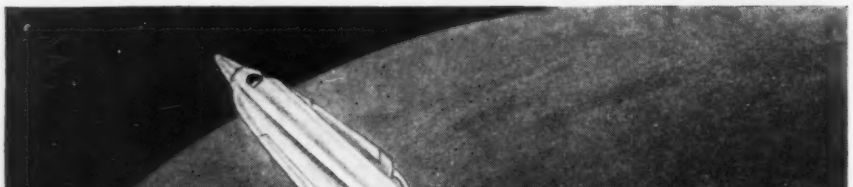
FOR MORE INFORMATION CIRCLE 28 ON INQUIRY CARD

MARS outstanding design **SERIES**



brings 'em back alive

Today's burning problem in space flight is how to ease a rocket safely back to earth, without being consumed by the metal-melting friction of our dense atmosphere. Design Engineer Carl J. Rauschenberger's ingenious suggestion is a pair of wings, locked forward at blast-off, later folded back into flying position (insert) by hydraulic cylinder controls for a slow, safe descent. Mr. Rauschenberger also envisions a retractable glass nose cone, heatproof to withstand the take-off, drawn back to admit air to a jet engine on the return flight.

This outstanding solution to a timely design problem may already exist in working drawings on somebody's drafting board, or even in mock-up form. But whether a project is developed today, tomorrow or the year after next, it will always be important to shape ideas into realities with the best of drafting tools.

In pencils, of course, that means Mars, long the standard of professionals. Some outstanding new products have recently been added to the famous line of Mars-Technico push-button holders and leads, Lumograph pencils, and Tradition-Aquarell painting pencils. These include the Mars Pocket-Technico for field use; the efficient Mars lead sharpener and "Draftsman" pencil sharpener with the adjustable point-length feature; Mars Lumochrom, the color-drafting pencils and leads that make color-coding possible; the new Mars Non-Print pencils and leads that "drop out" your notes and sketches when drawings are reproduced.

The 2886 Mars-Lumograph drawing pencil, 19 degrees, EXEXB to 9H. The 1001 Mars-Technico push-button lead holder. 1904 Mars-Lumograph imported leads, 18 degrees, EXB to 9H. Mars-Lumochrom color-drafting pencil, 24 colors.

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FOR MORE INFORMATION CIRCLE 29 ON INQUIRY CARD

Tubing Joint For Hi Temp

A Marman Conoseal Tubing Joint for connecting tubing and ducting of dissimilar metals subject to extreme temperatures is of all-metal construction, with a compression type metal gasket that achieves the flexibility and sealing characteristics formerly possible only with organic seals. It assures perfect fluid line seal even at extreme temperatures from −300 degrees F to +1600 degrees F, at pressures to 6000 psig, and withstands axial deflections as high as 1/16 inch without sacrifice of sealing qualities. Designed primarily for the aircraft and guided missiles fields, it is applicable to high pressure pneumatic systems, liquid oxygen systems, and fuel systems. Standard sizes of from 1 inch to 12 inches OD tube sizes are available from stock, and special sizes may be engineered to customer's design requireemnts. Aeroquip Corp., Jackson, Michigan.

Circle No. 190 on Inquiry Card

Heat Exchanger Tube with Internal Fins

Impervious graphite tube with internal low fins more than doubles the inner surface area of graphite shell and tube heat exchangers. Twenty-three fins, each 3/16-inch high, increase the inner surface to 2.6 times that of a plain ⅞-inch ID tube. Fins twist helically through the length of the tube, providing turbulent flow at right angles to their longitudinal axis, thus accentuating the difference between streamline and turbulent flow, and increasing the heat transfer coefficient as fluid velocities increase. National Carbon Co., Division of Union Carbide Corp., New York, N. Y.

Circle No. 185 on Inquiry Card

TRANSLATIONS

ANDREW R. MACANDREW
Foreign Editor

Thin Dielectric and Semi-Conductor Layers

The dependence of conductivity of thin layers on field intensity has been insufficiently investigated, according to Yu Volokobinski in Doklady Akad Nauk USSR 1957. His paper describes results of his experiments to determine the relation between electrical conductivity of thin layers and their electrical stability.

Mr. Volokobinski says on the basis of his experiments that electrical resistance of thin dielectric and semiconductor layers varies with voltage, temperature, and material.

Layers of MgO, Al_2O_3, ZnO, CdS, NiO, Ta_2O_5 and Nb_2O_5, 30-to-1000 Angstroms thick, when tested showed in many cases a sharp jump in current at a specific voltage. This voltage was not related to the destruction of the layer, showing that the increase in conductivity does not necessarily result in spark-over. In some cases the spark-over voltage of the dielectric layer was much greater than that at the jump point. For several systems, such as aluminum oxide, the current became more proportional to the voltage as the temperature rose.

Current through an oxide layer covering tantalum, Ta_2O_5, increased exponentially with voltage to the immediate vicinity of the spark-over point (0.3 to 0.4 volts), became proportional to voltage and then jumped at the spark-over. The limit of the current intensity that will not cause the destruction of the layer (spark-over) is 0.2 ampere.

Volokobinski used as one electrode a tablet of Cu_2S, 3mm in diameter by 0.5cm² in area. This was fastened to the oxide or sulfide layer of the other metal which acted as the other electrode. This set-up is similar to that for the volt-ampere characteristics of semiconductor rectifiers.

Transfer of metal ions was observed from the underlayer into the Cu_2S which has a gap conductivity. The presence of the transferred ions in the Cu_2S was revealed in some cases, by spectral analysis and was manifested by the appearance of rectifying properties of the system under study. As the layer was heated by the current passing in some limited sectors, the ionic current was produced.

The oxides and sulfides listed in the third paragraph are arranged approximately in the decreasing order of the relative ionic proportion to conductivity. In the case of the layer of Nb_2O_5, the ion transfer was very small.

The resistance of the layer for an effective voltage of less than 0.2 volts is considerable. Then it decreases and the current rises sharply. The current increase is related to quantum mechanics effects and the curve of current as a function of voltage has a complicated shape. As the voltage decreases, resistance of the layer increases again and regains the original value.

If the voltage is increased above 0.2 volts, the transfer of Nb to Cu_2S becomes noticeable and a straightening appears. When the value reaches 0.4 to 1.0 volts, spark-over of the layer occurs.

A relatively high voltage was used in another experiment in which a tablet of tellurium was placed on the oxide layer covering aluminum. The author reported high voltage caused a spark-over and welded the tablet to the aluminum with an intermediate layer. This layer had a high resistance for low voltages. When the voltage was increased to 8.4 volts, the resistance declined sharply and a sharp jump in current occurred. The value of the voltage causing this jump varied little from case to case. When the voltage was reduced to 6.3 volts, the resistance returned to the original value.

Theorizing about the results of his experiment, Mr. Volokobinski says: "The following assumptions may explain the above findings. The spark-over of a layer is its destruction and requires a determinate energy quantity. This energy results from the heating of the layer by the passing current.

"The resistance of a thin layer decreases for low voltage. The amount of heat produced per time unit is small and since the heat conductivity is adequate no destruction of the layer occurs. Thus the passage of a strong current by itself without the heating of the layer will not cause its destruction and when the voltage is reduced the resistance of the layer is restored.

"The spark-over is connected with the destruction of the layer resulting from its being heated by the passing current and is a secondary phenomenon."

He concludes with a suggestion that further, more detailed study of volt-ampere characteristic be made to determine the nature of the processes taking place in thin layers.

This paper originated in the Russian periodical *Doklady Akad Nauk USSR*, vol. 113, p 1023, issue 5, (1957).

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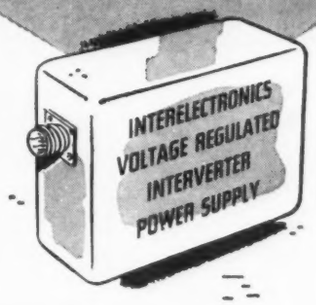

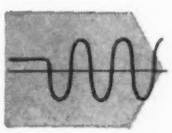

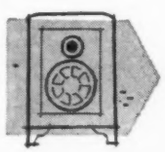

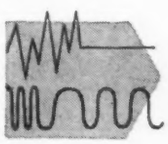

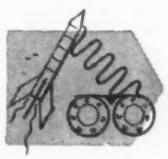

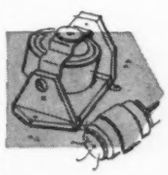

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Reliability Testing

Most equipment malfunctions are caused either by catastrophic failures which occur in a random fashion or by performance degradation (wear-out) failures. Immature designs often stress parts beyond their best operating limits making wear-out failure a serious factor. As a design matures, however, the safety factors on the stress of each part become large enough to reduce the effects of wear-out. In well designed systems degradation failures constitute only a small percentage of total failures. This is particularly true of systems designed for preventative maintenance to replace such known short life parts as magnetrons, vibrators, motor brushes, etc.

In general, new equipment can be engineered so that the contribution to equipment operational failures from other than random catastrophic failures is less than 5%. For this reason it has become common to measure equipment reliability in terms of the meantime-between-failures where occasional wear-out failures appear as indistinguishable contributions to the total.

Use conditions sometimes become more extreme than were planned for in the design. When this happens, the wear-out failures can become an appreciable part of the total failures resulting in a rise in the total failure level. This fact can be used as a powerful tool to determine if parts are being improperly stressed.

If the designer sets as his goal a design that will make the best use of each part then he can use as his measure of success the elimination of the wear-out-type failure as a factor in his final equipment failure rate. This means that the successfully engineered equipment will exhibit a normal operating period characterized by a constant average failure rate. The magnitude of this failure rate will be the sum total of the individual *random* failure rates of the component parts. All mature designs exhibit this characteristic when used for the purpose and in the manner for which the design was perfected.

Designing complex electronic equipment so that no circuit will be critical of the possible variation in part parameters that might occur in normal use is a major engineering problem. Unless such a design is accomplished, however, the failure rate of the equipment can be many times as large as the sum of the part failure rates that can be expected of the same parts when they are used more effectively.

Many experts in the equipment manufacturing industry are working on techniques required to achieve mature designs for new equipments. This article reviews the theory and statistical tools helpful in determining if this modern advanced engineering goal has been achieved in specific cases. Testing techniques based on this theory and analytical procedures employing new statistical tools are presented.

Many equipments to which these tests might be applied would be found to be inadequately engineered. The fact that many of these would also be the best available in the field suggests the magnitude of the engineering and reliability control task ahead.

SETTING A RELIABILITY GOAL

Some electronic parts fail even while they are sitting on a shelf. This is the inevitable result of the forces of time and environment acting

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Based On Poisson Distribution

on the unpermanent characteristics of all material. Some materials have more permanent characteristics than others. Even our most permanent materials are constantly changing –aluminum dissolves in water, toughest steel is embrittled by absorbing hydrogen. In addition to chemical changes that go on continuously, bombardment of materials by cosmic rays and other forms of radiation cause nuclear and other changes.

Because materials of various sorts are combined into electronic parts by a variety of technical processes in accordance with different designs, and by groups of humans, variation and change is unavoidable. When the part designs are not the best, when the raw material controls and process controls could be improved, the resultant products have limited inherent reliability. This reliability can be further degraded by misapplication or it can be improved by special application, but it can never be made perfect.

For a given design and manufacturer there is an optimum or maximum reliability potential for each part, which can only be realized in an equipment by means of exceptionally good engineering. If the optimum failure rate for each available part as degraded by normal handling and supply conditions can be determined, this value can serve as a measure for the success of the engineering application. The sum of the optimum part failure rates will constitute the upper limit of the equipment reliability.

When extreme complexity causes the sum of the optimum failure rates for the available parts to exceed the failure rate specified for the equipment it is possible to work this principle in reverse. By this method goals for the required failure rates of parts can be established from an analysis of the equipment goals and part quantities. Parts must be secured that will be capable of achieving the desired low failure rates under certain conditions of use. The designer then must plan the circuitry and local environment for each part to supply the necessary conditions. Success of the engineers' efforts and maturity of the design will be proven by how close the equipment comes to realizing the optimum reliability potential in the parts.

Nearly all types of parts can be built to obey the exponential failure law for a reasonable period of time and to exhibit an extremely low failure rate during this period. Actual failure records on commercial and military equipments show that some capacitors and resistors, for example, are in use which reveal failure rates in the order of 10^{-6} per hour or better. Other parts also show that long life and low failure rates are possible to achieve. The question is how long and how low these values can be pushed in respect to a given set of project conditions.

Many engineers will say that talking in terms of part reliabilities in the order of even one part in 10,000 or one part in 100,000 is useless. They feel that the cost of obtaining this reliability is prohibitive. Let me point out, however, that the age of complex electronic equipment has caught up with us. One computer alone may have hundreds of thousands of series type parts, any one of which may cause an equipment failure. Daily, industry is shipping military equipments containing thousands of parts. Every one of these equipments, to do its job, must contain parts whose failure rates are in this required extreme reliability range.

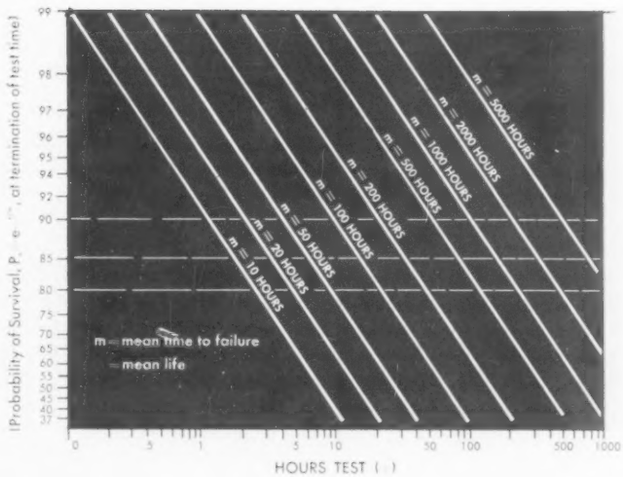
m = 10 HOURS
m = 20 HOURS
m = 50 HOURS
m = 100 HOURS
m = 200 HOURS
m = 500 HOURS
m = 1000 HOURS
m = 2000 HOURS
m = 5000 HOURS
m = mean time to failure
= mean life
HOURS TEST ( )

FIG. 1—Exponential failure law showing relationship between survival probability and hours of test for various values of mean time to failure, m.

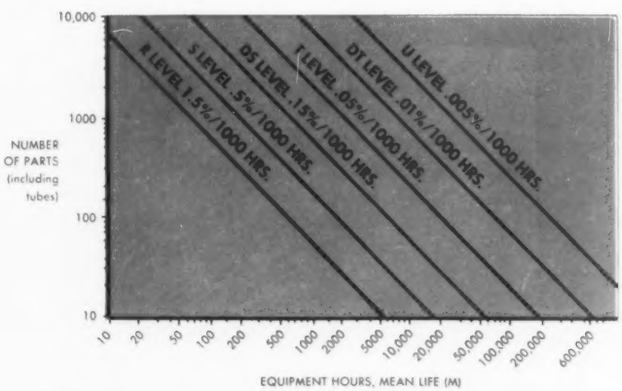
R LEVEL 1.5%/1000 HRS.
S LEVEL .5%/1000 HRS.
QS LEVEL .15%/1000 HRS.
T LEVEL .05%/1000 HRS.
DT LEVEL .01%/1000 HRS.
U LEVEL .005%/1000 HRS.
NUMBER OF PARTS (including tubes)
EQUIPMENT HOURS, MEAN LIFE (M)

FIG. 2. Relation between average failure rate per part and mean life, m.

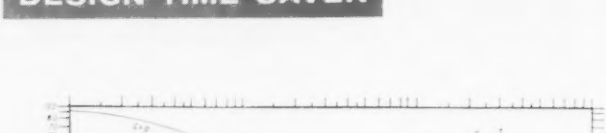

FIG. 3. Family of curves representing the probability distribution in the normalized time domain of exactly c failures, where c is any of a series of whole numbers.

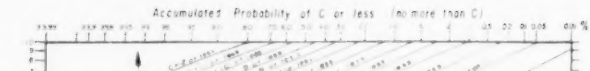

FIG. 4. Family of curves showing accumulated probability of c or less failures and of c or more failures for various values of normalized time.

Many modern equipments being shipped are not reliable. But equally important, many of them are. For these equipments an apparent miracle has been performed somewhere between the part buyers desk, where reliability is only a hope, and the equipment shipping platform where dependably low failure rates are the rule.

The fact that part reliability screening is being accomplished during the equipment manufacturing and test operation is daily proof that parts with extreme orders of reliability can be obtained. The question is: Are we generally obtaining the best reliability possible and in the most economical manner? The answers in most cases must be a resounding negative. This puts the problem squarely up to the reliability experts. How can we obtain the reliable parts we need at a reasonable cost and know we are getting the reliability we specified?

To decide what reliability we need let us consider a 6,000 part airborne equipment. The tactical use of this device requires that it shall have no failures in at least 85 percent of the equipment while operating on a 24 hour mission. These are reasonable figures so let us investigate what they mean in terms of part reliability.

When given this assignment your statistician would properly invoke the exponential failure law. This law is expressed as

$$P_s = e^{-t/m},$$

where P_s = the probability of survival at the termination of the test time, t, for an equipment whose mean time to failure is m. This so-called "law" is not applicable to all equipments but it has been found to apply very closely to the behavior of good equipments. Unreliable equipment will often not obey it because the failure rates are not constant with time. Also the failure rate average for these is usually at a much higher value. If the law does not apply to your equipment it will most probably have too short a life and too high a failure rate to give the necessary reliable performance. Since you are interested in how good your equipment must be to meet the contract need, it is valid to use the exponential law to calculate the requirements.

The exponential failure law illustrated in Fig. 1 shows the relationship between equipment reliability or the probability of survival and the hours of test for various values of mean time to failure, m, often called mean life. In the case at hand we would enter the chart of Fig. 1 at 85 percent on the left and at 24 hours at the bottom and find that this tactical requirement calls for a mean life, m, of about 150 hours. To find what this means in terms of the average failure rate per part we can use the chart in Fig. 2.

Figure 2 illustrates the relationship between the number of parts in an equipment, its required mean life, and the average failure rate per part. Shown also are the arbitrary failure rate levels established by RCA. Entering this chart at the left for 6,000 parts and at the bottom for 150 hours we find the average part failure rate to be at the RCA-DS level of 0.15 percent per 1000 hours. In other terms this is a failure rate of 0.0000015 per hour. It is several orders of magnitude below the levels usually considered reasonable for commercial procurement. Such a low figure cannot be proven by any of the usual quality acceptance procedures or measured by the customary inspection tests. How then can this reliability be measured?

TESTS BASED ON THE POISSON DISTRIBUTION

The familiar individual Poisson term $(e^{-a}a^c/c!)$ can be modified for reliability purposes by substituting normalized time, t/m, for the expectancy, a, where t is time of test and m is the mean time to failure for an equipment. The infinite series representing a value of 1.0 thus becomes as follows:

$$1 = e^{-t/m} + e^{-t/m}(t/m) + [e^{-t/m}(t/m)^2]/2 + [e^{-t/m}(t/m)]/3 + \ldots$$

Each of these terms gives the probability of exactly c failures. The first term is the probability of zero failures occurring in time t, when the mean time to failure is m. The second term gives the probability of exactly one failure in t/m normalized time units. The third term is the probability of exactly two failures occuring in t/m normalized time units, etc. These successive terms can be plotted as a family of curves as shown in Fig. 3. Each curve represents the probability distribution in the normalized time domain of exactly c failures.

To explain the practical significance of Fig. 3 more

fully, assume that we repeatedly test an equipment for a length of time equal to its mean life, m, (test time $t = m$, and $t/m = 1$). From Fig. 3 we would expect to observe zero failures about 37 percent of the time, one failure about 37 percent of the time, two failures about 18 percent of the time, three failures about 6 percent of the time, four failures only about 1.5 percent of the time, and so on.

Another way to use Fig. 3 is to predict the probability of specific numbers of failures that will occur for a given equipment during tests of various lengths. Suppose the equipment being tested has a known mean life of 100 hours. In a test of 50 hours where $t/m = 0.5$, there is only an 0.1 percent chance of four failures, a 1.2 percent chance of three failures, a 10 percent chance of two failures, a 30 percent chance of one failure, and a 60 percent chance of no failures. On the other hand if we choose a test of 500 hours for this equipment where $t/m = 5$, then from Fig. 3 we can expect an 0.6 percent chance of no failures, a 3.3 percent chance of one failure, an 8.5 percent chance of two failures, a 14 percent chance of three failures, and a 17 percent chance of four failures occurring. There is also now a 1.8 percent chance of ten failures, about a 3.7 percent chance of nine failures, and a 6.5 percent chance of eight failures, etc.

Since we are interested in establishing a limit to the number of failures that can be tolerated as acceptable in a test and not the probability of exactly c failures, it is necessary that we deal in terms of cumulative probability. For example, we might be interested in the probability of three or less failures in a certain normalized time. This can be found simply by summing the amplitude of the 3, 2, 1 and zero curves at the specified interval of normalized time. If these summations are made at each successive interval of t/m they can be plotted as the family of curves shown in Fig. 4. The cumulative probability of c or less failures is plotted at the top of this specially-ruled logarithmic probability paper. The normalized time units are plotted at the left and the c for each number of "failures or less" is labeled on the top side of each curve.

Now it can be seen that the scale at the bottom of the graph is one (1) minus the scale at the top. Since the probability of "c or less" equals one minus the probability of "$c + 1$ or more" then the bottom scale also applies to the same curves but with one (1) added to each c. In other words, the curve labeled "$c = 1$ or less" when read at the top is the same curve as "$c = 2$ or more" when read at the bottom. The values for "c or more" are the cumulative probabilities from a certain c to infinity. These values can be checked by reference to the "Poisson Exponential Binomial Limit" Tables No. 2 by Molina (D. Van Nostrand). In these tables use a for t/m and c in the usual fashion.

Before considering the tests based on this family of curves we should point out that the value of 92 percent read from Fig. 4 for the probability of two or less failures when $t/m=1$ is the cumulative probability (the sum) of the individual terms as shown in Fig. 3. Thus, $P_{2\ or\ less} = P_2 + P_1 + P_0 = 18\% + 37\% + 37\% = 92\%$.

An example may be helpful to show how Fig. 4 may be read. Suppose we have an equipment whose mean-life, m, is known to be 100 hours and we decide to test it for 100 hours, where $t/m = 1$. Since the occurrence of the failure is random, there is a certain probability that any particular number of failures will be observed during the test period. From Fig. 4 we can read that there is a 92 percent probability that we will observe two or less failures and a 74 percent probability that we will observe one or less failures. We can also read from Fig. 4 that there is only an 8 percent probability of observing three or more failures.

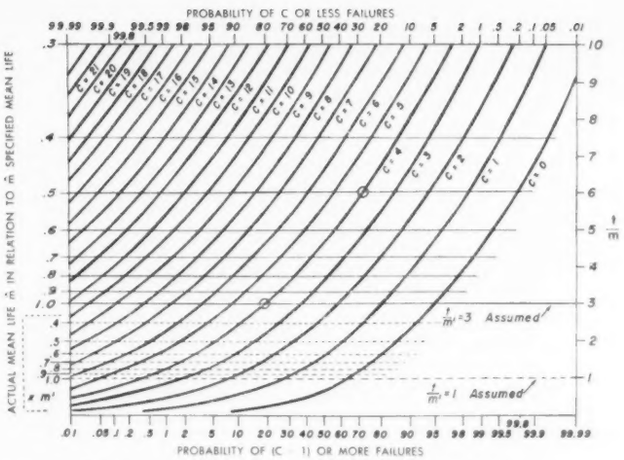
PROBABILITY OF C OR LESS FAILURES
ACTUAL MEAN LIFE m IN RELATION TO m SPECIFIED MEAN LIFE
PROBABILITY OF (C − 1) OR MORE FAILURES
Assumed
Assumed

FIG. 5. Family of curves for determining the effect of actual equipment failures being greater than a specified minimum.

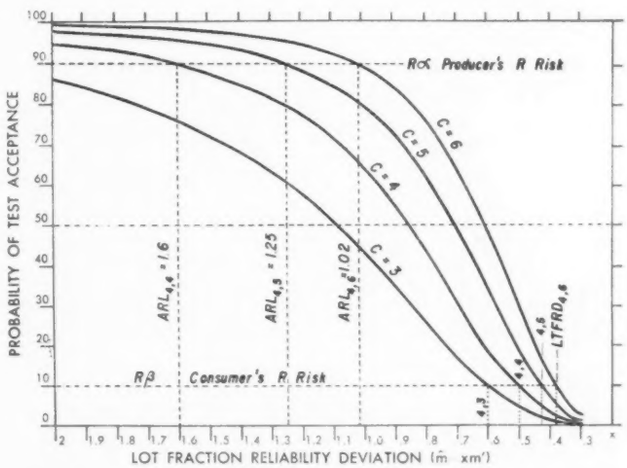

FIG. 6. Reliability operating characteristic curves for a normalized time level (t/m') equal to 4. (RO-C_t).

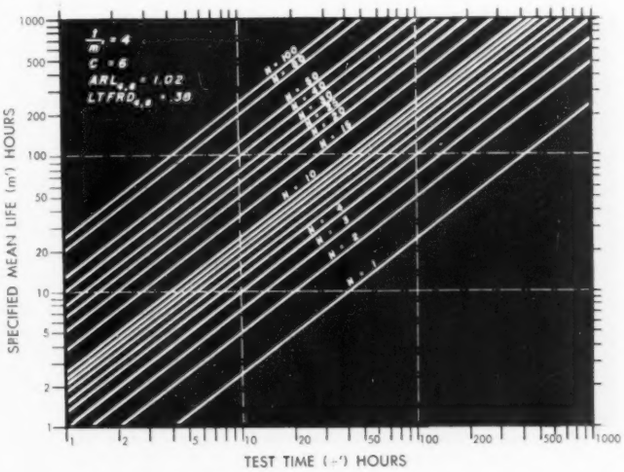

FIG. 7. Typical equipment reliability test based on RO-C_{10} curve of Fig. 6.

In this example we knew the actual mean-life, m, before starting our test. In the practical case we usually have a specified mean-life m' for an equipment whose actual mean-life, m, is unknown. We desire a test which will enable us to draw some conclusions about the relative values of m' and m from a consideration of the number of failures that occur. The emphasis is usually on proving

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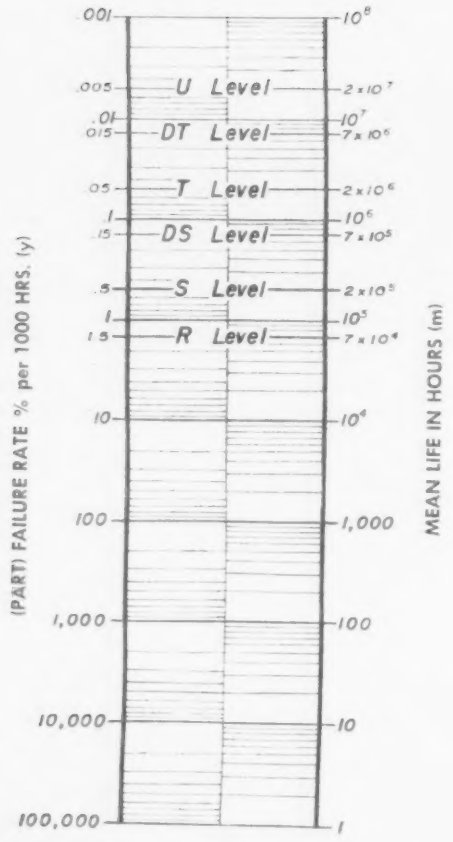

FIG. 8. Relation between failure rate, λ and mean life, m.

with a certain approximate confidence that m is at least as large as m'. This ratio of m/m' is hereinafter referred to as the *reliability deviation*.

In using the family of curves in Fig. 4 the test engineer establishes a test time and a related acceptance number of failures that would be appropriate if the equipment being tested is as good as the specification (that is, if $m = m'$). For example, if the specified m' is 100 hours, he may decide to test for 300 hours. Accordingly, he can read from Fig. 4 that the probability at $(t/m = 3)$ for 4 or less failures is 82 percent. In other words, if the equipment he is testing has an $m \geqq m'$ then there is an 82 percent chance that no more than four failures will occur during the 300 hour test. If five or more failures occur the equipment is immediately suspect and further testing is called for. The reason for this decision is that if $m \geqq m'$, there is only 18 percent or less chance that 5 or more failures will occur, only an 8 percent or less chance that 6 or more failures will occur and less than a 3 percent chance that 7 or more failures will occur.

Now if m is only half of the specified m' when the engineer assumed it was equal, the probability that this error will be detected in the test is quite high. Figure 5 is presented to make the reason for this more obvious. Although the engineer is operating on the $t/m' = 3$ line and using $c \leqq 4$ as the rejection criteria, if $m = 0.5m'$ then the equipment is operating on the $t/m = 6$ line. There is only a 28 percent chance there will be 4 or less failures during the 300 hours test and thus a 72 percent chance there will be 5 or more failures. If the disparity between specified and actual m is as much as $m = 0.3m'$ then the equipment will be operating on the $t/m = 10$ line and there will be a 97 percent chance that there will be 5 or more failures during the 300 hour test.

In other words, the charts of Fig. 4 and 5 provide a method of establishing *operating-characteristic* curves for reliability tests. From these curves and charts it is possible to calculate the probability that an equipment being tested does not meet the specified reliability.

Typical reliability operating characteristic curves hereinafter called RO-C curves are shown in Fig. 6. These curves are based on a normalized time level of $t/m = 4$. The proper label for these curves is thus RO-C_4 and for a particular curve such as that based on an acceptance number of 6, the label is RO-$C_{4,6}$. This particular curve is interesting because it crosses the 90 percent probability-of-test-acceptance line very nearly at the point where the reliability deviation ratio, m/m', equals 1. This fact can be interpreted to mean that when an equipment is tested to a time $t = 4m'$ there will be a 10 percent producer's risk that the equipment will be rejected by the test if $m = m'$ and the acceptaace number is 6.

For example, suppose an equipment whose specified mean life, m', equals 100 hours is tested for 400 hours and is to be accepted if there are 6 or less failures. If the m is actually equal to the 100 hours specified, there is still a 10 percent chance that the equipment will be rejected by the test (that it will by chance exhibit more than 6 failures). On the other hand, and from the other end of the curve, an equipment m may be as bad as $0.38m'$ (38 hours instead of 100) and still have a 10 percent chance of being accepted by the test. It can be seen that the higher the acceptance number, the steeper the slope of the curve and the shorter the spread between the value of the reliability deviation related to the 10 percent producer's risk, $R\alpha$, and that related to the 10 percent consumer's risk, $R\beta$. These values of deviation are called respectively the *acceptable reliability level* (ARL) and the *lot tolerance fractional reliability deviation* (LTFRD).

A typical reliability test based on the RO-$C_{4,6}$ curve of Fig. 6 is shown in Fig. 7. This curve relates the specified mean time to failure, m', in hours to the test time, t, in hours for various quantities of equipments. From this it can be read, for example, that if you test four equipments for 100 hours and observe 6 or less failures during the test you will have proven with a 90 percent confidence that the actual mean life m, is greater than 38 hours and less than 102 hours.

PART RELIABILITY TESTS

"Mean-time-between failure" in hours is convenient to use for equipments because it has a realistic application violating no intuitive concepts. When this figure of merit is applied to parts, however, it must be understood that the actual figure-of-merit being considered is the failure rate during the first few thousand hours, which is equivalent to a mean life of hundreds of thousands of hours if no material degradation or other effects of age enter in. It is more convenient, therefore, to deal in terms of failure rate, λ, for parts and mean life, m, for equipments.

Because the failure rate figures are so very small for highly reliable parts dealing in terms of failure rate per thousand hours has become customary. Since the failure rate is simply the reciprocal of the mean life this relation can be illustrated as in Fig. 8, which shows the failure rate levels R through U established as reference levels at RCA.

A part reliability test planned for use in these higher reliability levels and derived from the RO-$C_{4,6}$ curve is shown in Fig. 9. From this curve it can be seen that parts to the DS level which have an average failure rate of 0.15 percent per 1000 hours can be accepted if 6 or less fail-

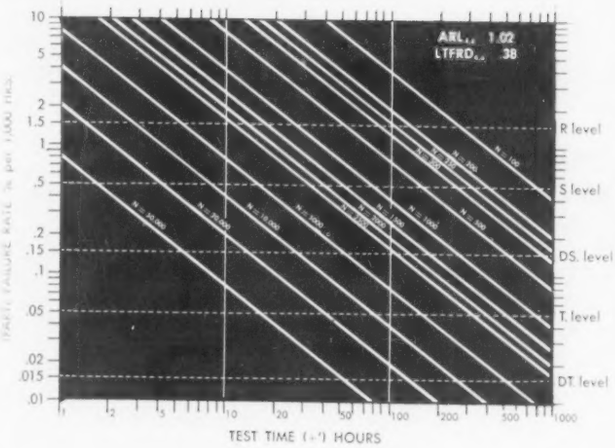

FIG. 9. Typical part reliability test based on RO-$C_{4,6}$ curve of Fig. 6.

ures is experienced in a test lot of 1000 parts on test for 230 hours. It must be remembered, however, that this test is based on the RO-$C_{4,6}$ curve. And from this curve (Fig. 6) there is a 10 percent chance that parts accepted by this test may be as low as 0.38 as good as specified (that is, they may have a failure rate of 0.4 percent per 1000 hours). There is also a 50 percent chance that the parts accepted by this test may be only 0.6 as good as specified or have a failure rate of 0.25 percent per 1000 hours. For most practical purposes these risks are reasonable and this test may be very convenient to use. Different RO-C curves may be used to establish tests for other risk requirements.

RESPONSIBILITY FOR RELIABILITY

Reliability is primarily an engineering responsibility because it is in the basic design that inherent or built-in reliability is determined. Greater emphasis during the design stage to provide a more mature design that meets service use conditions results in less operational deterioration and fewer failures. A design calling for the best available parts to be used in circuits that allow wide variation in part capabilities and use environment is the key to high reliability.

However, even the most mature design supported by the best part specifications cannot result in a reliable equipment unless the production operation brings out the maximum potential of the engineering work. Quality control must insure that the various reliability goals established during the design operation are met during the production phase.

While quality control cannot add to the reliability incorporated in a design it has the most vital role in insuring that manufacture does not degrade this potential. In addition, quality control can serve as one of the best sources of feed-back information to engineering concerning the success of the design and part specification.

During the development of the engineering design and the test of prototypes, analyses and measurements are made that provide reliability goals for quality control. Specific figures for the required failure rates of parts, components and equipments are established which the quality control organization must use as a basis for the production control operation. It can be seen from this how much reliability control depends on teamwork between all phases of a production operation. But reliability testing based on the Poisson distribution can be generally beneficial to all.

This paper was presented at the Fourth National Reliability Symposium in Washington, D. C., January, 1958.

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Screws
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TERMINAL BLOCKS
(Molded, Barrier-type)
with ANGLED TABS Made
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Other terminal blocks available in approved materials range from subminiature (shown) to jumbo (90 amps).
SINGLE & DOUBLE POLE
ELECTRONIC SWITCHES
KULKA
Toggle handle, aircraft type. Bakelite housing. With screw terminals, or solder lugs. DC, or AC up to 1600 cycles. One-hole mounting.
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MANAGEMENT

A COMPREHENSIVE APPROACH TO INDUSTRIAL RESEARCH EVALUATION

James Brian Quinn *Assistant Dean, Amos Tuck School of Business Administration, Dartmouth College*

The process of evaluating research results is basically one of judging past performance for the purpose of guiding future action. Any evaluation system that does not have action as its objective becomes simply an exercise in logic and, as such, has no value to an enterprise.

To judge past performance, results must first be observed and then compared with some established criteria. Judgments should provide a logical basis for planning future action to exploit observed results or to initiate a new phase of the research program.

Before attempting to establish criteria for appraising research results, we need to analyze research activity to identify the types of results it produces.

CLASSIFICATION OF RESULTS

Direct and Indirect. Research does not directly produce sales, or royalties, or profits, or process savings. It produces only the technology upon which such economic benefits may be based. This technology which is the *direct product* of research, may take any of several forms. It may vary from elusive oral ideas, through written or drafted specifications or designs, to concrete materials, prototypes, processes, or products. For any of these forms of created technology to reach economic fruition they must be accepted and exploited by the remainder of the enterprise. In economic terms, research produces directly only *opportunities to exploit*, not the results of such exploitation. Proper exploitation of these opportunities by the remainder of the concern creates economic yield—the *indirect products* of research.

Phases of Research. Both direct results and indirect results could be further subdivided into those deriving from fundamental research, advanced development, or applied research. The more advanced phases of research yield both opportunities for commercial exploitation and for further technical exploitation within research.

Actually, of course, the line between the various phases of research is not clear cut. However, a thorough evaluation of research results should attempt to assess the relative cost and benefit of each.

Offensive and Defensive. An additional subdivision of research results into classifications of offensive and defensive further facilitates evaluation. Offensive results are those which primarily contribute to the development or exploitation of new markets for the sponsoring concern. They include development of new products, new markets for existing products, new processes for proposed products. Defensive results are those that primarily contribute to the maintenance or enhancement of the company's position in its existing markets. They include product improvements, process improvements, methods for salvaging wastes, development of new sources of raw material. Since widely disparate techniques are required for evaluating these two classes, they should be separated to the extent possible in establishing an evaluation structure.

Results of research are identifiable as to potential end use only when they derive from the advanced development or applied phases of the research program. Fundamental research cannot normally be characterized as useful for offensive or defensive purposes until more applied experimentation develops its specific applications. In evaluating research effort it is essential, therefore, to consider fundamental research results separately from those of more applied phases.

Over-All Results. Finally, there are some broad benefits of the research program that may not be attributable to any single phase of the program but which derive from a combination of all phases. These benefits might be classified as the products of the "over-all" research effort. Examples of this kind of result include: a reserve of technical knowledge to solve future problems, good will for the company as a technical leader, avoidance of technical difficulties, better technical planning, etc.

APPROACH TO EVALUATION

Having indicated a general structure of the kinds of results a comprehensive research evaluation system must consider, we can now develop an approach to the appraisal of each type and of the program as a whole.

Direct Results. Direct products of research are primarily technical in nature. In economic terms these technical products represent *opportunities to exploit.* A thorough appraisal of the direct results of research requires: (1) technical evaluation of each segment of the program and (2) economic evaluation of each segment in terms of *opportunities to exploit.*

Indirect Results. The indirect products of research are economic in nature. They represent the *actual* economic yields obtained from exploitation of research results. To obtain a full understanding of the impact of research on

the operations of the enterprise it is essential to make an appraisal of indirect results. However, it should be emphasized that measurement of the indirect results does not constitute measurement of the output of the research effort. It merely gauges the benefit the whole concern has obtained by the exploitation it has chosen to make of the direct results. This benefit is vastly influenced by many factors other than the adequacy of the research effort.

Over-All Results. Appraisal of research thus requires at least: (1) a technical evaluation of direct results, (2) an economic evaluation of direct results, and (3) an economic evaluation of indirect results. One more appraisal is required for a comprehensive set of guides to action: evaluation of how well the research effort fulfills the specific technical needs of the sponsoring concern. A research program, no matter how skillfully and efficiently executed at the lab bench, will make its maximum contribution to the sponsoring concern only if it is properly integrated into the operating needs and objectives of the concern.

TECHNICAL EVALUATION OF DIRECT RESULTS

Technical evaluation involves judging the adequacy of technical accomplishment during a period of research without regard to its utlimate commercial worth. Technical evaluation is concerned with appraisal of: (1) the efficiency with which the planned technical results were accomplished and (2) the quality, or degrees of creativity and proficiency, evidenced in the results.

In certain respects the technical evaluation of a research project may be compared to cost and quality control estimates in a production operation. Evaluation of the efficiency and quality of accomplished results is no more than a comparison of the actual cost or quality of the results against a standard.

Generally, it is not possible to predict the outcome of research sufficiently to establish projected standards for evaluation of its efficiency or quality prior to the start of technical work. Standards against which research performance is to be compared must often be determined after the work has been completed.

Efficiency. The relative efficiency of research results is the ratio between the time and cost consumed in doing the work and the time and cost that would have been consumed by the *best method* of doing the work.

Judgments of efficiency require appraisal of both method of attack, and speed and skill with which the work was accomplished.

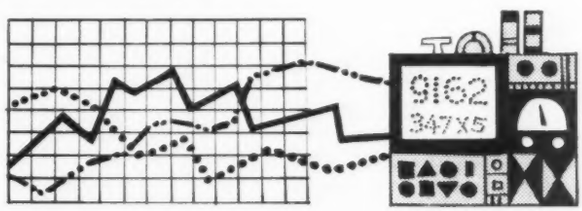
The research executive is limited to judging actual progress against the best method he can conceive of doing the job. However, his judgment is no different from comparisons of actual production work against engineering standards. The engineering standards are simply the best way conceivable by the standard setters to do the job at the time the standards were set.

Judgments cannot be made concerning the efficiency with which unplanned results are created. Such results are often matters of accident or luck rather than skill or application. By experience it is possible to appraise the speed with which a scientist accomplishes a series of experiments or measurements he undertakes, but it would not be possible to evaluate the efficiency with which he obtained a fertilizer additive when he was really looking for an antibiotic.

Quality. The quality of research results is determined by two factors: (1) the creativity demonstrated in achieving a result, and (2) the technical proficiency with which a result was accomplished. Either or both may determine the quality—the utility for a given purpose—of the results.

It is rarely possible to establish in advance standards for the degree of creativity or technical proficiency a project will require. Again the research executive must await completion of the project before he can evaluate the creativity or technical proficiency in its development. Such standards are extremely obscure and notably subjective. However, this does not mean that judgments of these factors cannot be made realistically. Most research executives report that they can rank their personnel as to creativity and technical proficiency. These rankings are composite judgments of group performance on many projects over a long period of time. Unless such judgments are made there is no way to say whether a scientific team using even the "best approach" at "optimum speed" has produced the best results for the cost.

Neither in interviews nor in the literature have I found a single concern that relies heavily on quantitative techniques for the technical evaluation of its research program. There have, of course, been various experiments in this direction but none have yielded generally usable results. It would appear that at present management has no real alternative to its widespread reliance upon "composite management judgments" in technical evaluation of its research programs.



ECONOMIC EVALUATION OF DIRECT RESULTS

Economic evaluation of the direct results of research assesses the economic values directly created by the research effort against the costs of attaining those values.

There has been no dearth of quantitative devices for economic evaluation of research results. Erroneously, I believe, they have attempted to measure the direct research contribution by assessing the indirect results of the program, which are really effected by all functional groups in the concern, not by research alone.

Most quantitative evaluation techniques have attempted to establish some single figure as a measure of the total contribution of research to the sponsoring concern during a particular time period. This figure is usually based on the actual or estimated profit received or to be achieved by planned exploitation of results. Normally profits from new products, process cost savings, royalty income, and a share of the profits on improved products are considered and related to the cost of the research which made these profits possible. As yet, of course, the proponents of the various formulas have not been able to reach agreement on: (1) the time periods to be used in calculating; (2) the kinds of exploitation that should be included; (3) the weighting factors in the formulas; (4) the amount of credit to be given to research for the contributions; and (5) the levels of contributions to be considered inadequate, sufficient, or copious. No generally accepted standards have been established for an acceptable ratio of research contribution to research costs. Because of this lack of agreement, most companies have avoided quantitative evaluating for this segment.

But the most frequently encountered question is that of the share of credit that belongs to research and development. Is it really necessary to allocate to research a share of the profits realized from exploited research results? Past research investments are much like investments made in fixed plant, machinery, or in underground resources like mines. These assets represent *opportunities to exploit*

just as the results of past research do. In each case opportunities would be exploited by the whole concern. Few people would suggest that a share of the profits be allocated to the plant and equipment or to the mine. There is no need to credit a similar share of profits to research.

Past research efforts are capital investments. Research investments should be evaluated the same way as other fixed-asset investments. Fixed asset investments are normally appraised by comparing the operating effects of owning the asset against some alternative operating condition. The major problem in the economic evaluation of research, therefore, should be the selection of the proper alternative to the research investment.

There are two alternatives: (1) purchase the research outside the concern by royalty payments or by buying the work of independent laboratories, and (2) perform no research at all. If technical evaluation of the research program shows that the research has been handled in the most effective manner, buying research outside the concern could not have cost less and hence could not have yielded a return on investment. Even if technology were bought, it would still have to be evaluated. The alternative cost of not performing research is the loss of opportunities to exploit and thereby the loss of real and potential profits.

The only realistic way to express the direct results of a research program is to estimate the potential worth in dollars of the opportunities to exploit provided by research, and compare this potential with a similar estimate of the research cost of developing it.

Of course, research programs produce more opportunities to exploit than the sponsoring concern can possibly hope to fulfill. However, the sum of the worth of all *opportunities to exploit* rather than the worth of those actually exploited is the measure of the total direct product of research.

ECONOMIC EVALUATION OF INDIRECT RESULTS

Appraisal of the actual benefits obtained from research may be called the *economic evaluation of the indirect products of research*. This appraisal involves assessing the adequacy of the contribution by research to the profit position of the concern in relation to the investment required to obtain the contribution.

A reasonable statement of the actual incremental profit resulting from research is "The concern has realized (or will realize) X dollars in Y years by exploiting research-produced technology costing Z dollars." No attempt should be made to state that research produced X dollars of profits. The whole concern, not research, produced the profits.

Analysis of profits that would not have been possible without research appraises the alternative cost of not performing research. This appraisal enables company management to determine whether the company has realized sufficient additional profits from exploitation of research results to justify the research. No useful purpose is served by computing and allocating pseudo-precise credit to research.

To the extent that economic evaluation of total research helps to affirm or allay the confidence or suspicions of management about research, it is valuable; but as a guide to management action it has practically no utility. Over-all economic evaluation does not indicate the advisability of expanding or contracting the research effort or any of its phases, nor is it a guide to any other form of management action. Computing potential returns and actual profits from exploiting results of the various segments of the research activity is more apt to be useful in directing and controlling the program.

It is probable that the most useful subdivision of the applied phases of research would be into product lines. By identifying the profits from exploiting those segments, efforts can be balanced to achieve maximum yields. Those segments that are most and least fruitful can be examined to determine the reasons for their success and failure, and the program can be redirected accordingly.

In the more fundamental phases of research, a breakdown by areas of inquiry would seem most worthwhile. As one attempts to evaluate the more fundamental spheres in economic terms, he is forced to ask a negative question, "What major profits from research exploitation could not have been achieved without the support of this or that area of inquiry?" Without attempting to give credit to fundamental research for these profits, one can nevertheless estimate the alternative cost of not having done the research in each area. Using these estimates as guides over a long period of time, emphasis can be directed to the more profitable areas of fundamental research activity.

EVALUATION OF OVER-ALL RESEARCH

A research program can appear to be skillfully and efficiently handled and to be producing a large quantity of exploitable results and yet be less successful than it could be. It is reemphasized that a research program, no matter how skillfully and efficiently executed at the lab bench, will make its maximum contribution only if it is properly integrated into the operating needs and objectives of the concern. A comprehensive evaluation system must, as its final appraisal, judge the degree to which the research program achieves such integration.

Research Integration. The degree of integration of a research program is the relationship between the technical needs and desires of the sponsoring concern and the technical output of its research division. Unfortunately, there are no consistent measures of these two factors. However, there is one indication of improper integration of the company's research effort worth noting. If the research output is too low relative to the company need, the concern tends to lose its position in its industry because of inadequate technological support. If the research output is too high because the concern is unable or unwilling to exploit many of its results, exploitable technology remains on the shelves. Thus, the ratio between the direct and indirect products of research of a particular period would be an indication of research integration.

Management Evaluation. Proper integration of the research effort is achieved only when research executives perform certain management activities effectively. These include: (1) selecting areas for research that satisfy the technical needs of the concern; (2) attracting, selecting, and holding the best scientific talent to work in these areas; (3) appraising progress on research programs and leading research efforts along the most useful channels; (4) selling research results to the company to insure their exploitation and to obtain support of the research program; and (5) providing an atmosphere most conducive to skillful and creative scientific work. These are the management activities of planning, organizing, directing, controlling, coordinating, and motivating as they apply to research administration.

Top executives who do not have strong scientific backgrounds have no basis for evaluating the technical skill of the research executive. This they must take on faith. But they can appraise his executive talents on the same basis as they appraise similar talents in other executives. If his executive (non-scientific) activities are being properly performed, the research activity will achieve its greatest integration into the operating needs of the concern. END

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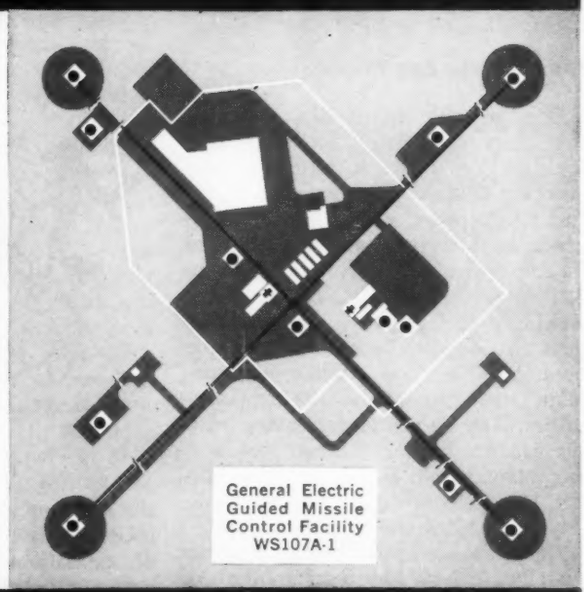
GRADUATE EE'S: GENERAL ELECTRIC DISCLOSES HIGH PRIORITY PROGRAM FOR ATLAS GUIDANCE SYSTEM. MANY POSITIONS OPEN IN ELECTRONIC MISSILE TECHNIQUES=

ACCURACIES ON ORDER OF 1 PART IN 10 MILLION

required for portions of G.E.'s ICBM ATLAS Guidance System



Delivering an ICBM over a > 5000 mile trajectory into the target area demands a guidance system of unprecedented accuracy—and this is the calibre of the electronic system General Electric engineers are creating for ATLAS.

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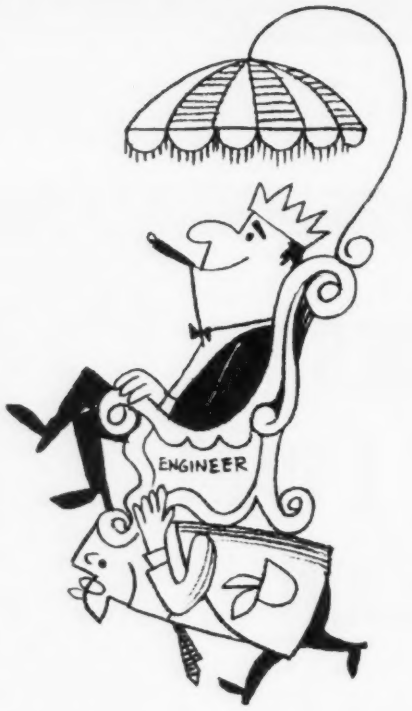

The Hen and Egg Problem

One of the frequently recurring topics at meetings of Engineering Societies deals with improving the "working climate" for engineers in industry. Speakers who address themselves to this problem generally lay the improvement opportunities at management's doorstep. Arch Patton of McKinsey & Company, Inc., management consultants, believes that in the creation of a good working environment, management has its responsibilities. But, he continues, to stop with this is like saying a team needs a competent coach; the statement is correct, but the coach must have adequate playing talent if the team is to win.

Mr. Patton compares corporate working climate with the legal framework governing the day-to-day environment in the community in which we live. When most people accept these laws and obey them, we have a good community climate. But when a major segment of the population considers these laws to be binding only on the other fellow, varying degrees of anarchy result. Thus, he points out, the community has an elaborate apparatus called government to maintain the agreed upon community environment called for in this legal framework. In effect this apparatus is designed to enforce discipline, if it is necessary, on the part of the few who regard themselves as above the common laws governing the community climate.

Patton believes that a good company environment also imposes discipline on management and employee alike. When management has determined company objectives, each member of the organization must accept his share of the responsibilities essential to accomplishing these objectives. Patton explained that a company's success depends upon an individual's performance of his responsibilities. Therefore, management must accept the responsibility for judging how effectively these individuals carry out their assignments and each individual must recognize that this is a necessary discipline.

HIGH SALARIES VS HIGH PROFITS

A recent compensation survey by McKinsey & Company, Inc., showed statistical evidence that a close correlation exists between high executive compensation and high corporate profits. For example, it indicated that the top paying company in each industry studied had a ten year profit increase that doubled the industry average and was ten times greater than the profit gain chalked up by the poorest paying companies.

Since profitability is a major objective of industry in a free enterprise economy, Patton thinks it fair to assume that the highly profitable companies in this survey generally have a good working climate. At least, a climate that produces high long-term profits should be considered a good one. Over the years, Patton has become reasonably familiar with compensation practices of many of the 71 companies participating in this survey. In his judgment the outstanding difference between the administrative practices of the high-profit and low-profit companies lies in the emphasis the top profit companies place on **performance** in giving promotions and merit increases. The low-profit companies, by contrast, tend toward a philosophy that places greater emphasis on seniority when promotion or salary increases are considered. Mr. Patton's interpretation of these statistics indicates that a good working climate goes hand-in-hand with above average profits; which, in turn, accompany a performance-oriented company administration. But Patton emphasizes if performance is to be the keystone of administration, it becomes critically important to establish a sound basis for judging the on-the-job effectiveness of the individual.

THE PROFESSION'S ATTITUDE

Does the engineering profession recognize that appraisal of individual performance is the key to a good working climate? Patton believes that there is evidence to the contrary. For example, he points out there is a sizeable body of engineering opinion that compensation in the profession should be governed largely by the number of years out of engineering school. It assumes that years of experience alone increase the value of the engineer to the company without regard for the kind of experience he may have had or the individual's capacity for and interest in self-development. Nor does it recognize that human beings reach plateaus of competence at varying ages, some early and some late. Patton also pointed out that this concept probably reflects the feeling among many engineers that management does not understand their problems, hence is not in a position to judge their performance fairly.

Another professional group, Patton points out, the teachers, have traveled to the logical end of this road. Most school systems now provide for mandatory salary increases based on years out of school with no variance for individual performance permitted. Anyone who has been on a school board will recognize the deadening effect of such a philosophy for it offers no reward for outstanding performance—except the right to look for a new job.

Patton also feels that the feeling on the part of many engineers that their profession is "different" from the average functional specialist in industry stems from the recent shortage of engineering talent. From the day they finished school, many of the engineers were courted by industry. They received high starting salaries and enjoyed a fairly sheltered work environment with a minimum of pressure to produce. In one company Patton found that it was paying its new graduate crop of engineers only one merit increase (ten percent) less than engineers recruited seven years earlier would be receiving today if one ten percent merit increase had been granted in each of the seven years since leaving school.

Another factor plaguing the administration of engineering salaries, Patton believes, is the dispersal of engineering talent throughout the average organization. Not too many years ago engineers worked in the engineering department, period. But now the manufacturing department may have as many engineers as the engineering department and like as not, the sales department is heavily staffed with engineers. Moreover in a sales-oriented business the sales engineer might be

worth considerably more than an equally competent engineer—technically—in the manufacturing or engineering department. The reason, Patton points out, is that a new requirement has been added to the engineering qualifications—the ability to sell. And this new ingredient, unfortunately, does not appear to be uniformly spread among all engineering graduates.

YARDSTICKS FOR COMPENSATION

Since other functional skills are as necessary to corporate life as engineering skills, the process of balancing out the compensation of older engineers with that of accounting, manufacturing, sales and other personnel is not easy, Patton grants. However he believes that management was mousetrapped when engineering salaries started to skyrocket, particularly in many engineering-oriented companies in which salary administration was not given high priority.

On the other hand, while industry has been working hard to catch up with mistakes of past administration of engineering salaries, Patton feels that engineers themselves have created an important roadblock to progress in this area by their resistance to an organized basis for appraising engineering performance. A salary administration program requires that some organized basis be found for judging job value. Patton admits that this is fairly simple when the yardstick of job value consists of company sales, goods manufactured, money handled and the like. But the engineer cannot be judged by the weight of the drawings he turns in—only on the quality and abundance of his work that counts. Patton reports that many companies have found it valuable to evaluate engineering positions even when resistance of the engineers to such a program exists. In many cases, he claims, when the basis for evaluating engineering positions was fully understood by the engineers, their resistance evaporated.

In one particular compensation study within an engineering-oriented company he found approximately half of the individuals had received merit increases in each of the past four years and these averaged approximately nine percent per annum. In another equally important department only one out of six people had received merit increases annually in this period and these increases averaged only four percent. This was possible because the company had no salary administration mechanism; one top department head was a tight-fisted individual while the other was liberal.

Patton believes that the problem of administrating engineering compensation is confused by the tendency in many companies to consider engineering administration as being more important than creative engineering. At least it frequently seems to work out that way; administration is paid more than creative professional skill. This may result from the fact that top management does not understand engineering problems too well, says Patton, and regards anyone who is able to handle them—and this means the administrators—as being pretty important people.

However it appears to Patton that this problem too is becoming less important as companies recognize the need for offering top professional talent an opportunity to earn a substantial income as professional people. "But if this is to be done effectively, the engineer must become comfortable working in an environment that involves performance appraisal as part of his professional life. Like the executive, the engineer makes his own jobs to a substantial degree. This being the case," says Patton, "it is unsound to ignore individual performance in establishing a salary administration program, for rewards should be based on results." END

Radar Calculator

A radar self-screening range calculator provides a jamming figure of merit for radar system engineers. The hand calculator with its simplified scale settings eliminates slide rule calculations formerly required to determine the distance at which signal energy received at the radar is large enough to show through the jamming noise. Radar designer, having determined a minimum acceptable figure of merit, can also use the device to alter design parameters without recomputing his entire problem.

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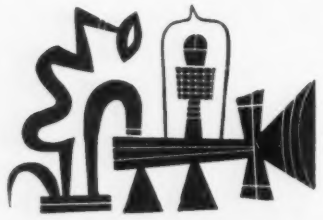


PRE-TESTING PRODUCT DESIGNS

Answers to Tough Questions

Nearly every product design project, at some phase of its development, has to run the gauntlet of such crucial questions as: "Will it sell at this price?", "Have we put in the right combination of elements at the price we are asking?", "Should we include additional features, and will the buyer pay their added cost?", "Should we offer only a basic product at a lower price?"

In essence these are decisions as to what to put into and what to leave out of the product, and at what price. John W. Barry, Vice President of Wallace Clark & Company, management consultants, believes that making such decisions blindly can be very costly as evidenced by the percentage of new product failures. However he points out that there are appropriate market-testing methods by which engineering executives can get reliable answers to these problems, methods which substantially eliminate guesswork and do so before designs are frozen and tooling costs are incurred. Among these methods he has found one that is uniquely suitable for pre-testing products still in the design stage.

CASE HISTORY

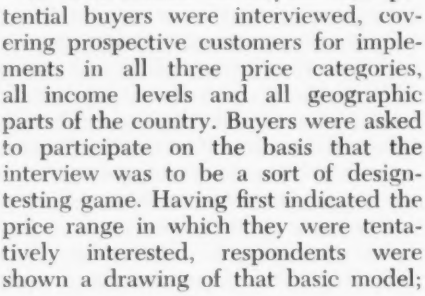
One of Wallace Clark & Company's clients was a manufacturer of an engineered consumer product. The manufacturer had a wide line — some 30 items — consisting of many variations in quality, consumer features and combinations of functional elements. He wanted to reduce his line, if possible, to one or two basic models.

Wallace Clark & Company's brief survey showed that there were three established basic price and quality levels in good demand; one at $20, one at $30, and a third at $40. The manufacturer's problem, reduced to its simplest elements, was what kind of a product to offer in terms of combinations of features and components for sale at each of these three price levels.

The manufacturer supplied Wallace Clark & Company with cost data on basic functional models stripped of virtually all elements that would build sales appeal into the products. These basic models were approximately comparable to those already on the market. These cost data were then translated into tentative selling prices at the customer level and than the costs were computed for every additional component "extra" and desirable feature that might conceivably be added to or incorporated in the basic functional model including one or two completely novel features; these costs were also translated into selling prices —thit is, margins were added.

Preparatory to an actual buyer survey, Wallace Clark & Company prepared a series of special drawings showing the basic functional model in pale outline but with each specific component or "extra" added in heavy ink on a separate drawing. This series of drawings were assembled into a folder and an appropriate questionnaire prepared.

A cross-section of buyers and potential buyers were interviewed, covering prospective customers for implements in all three price categories, all income levels and all geographic parts of the country. Buyers were asked to participate on the basis that the interview was to be a sort of design-testing game. Having first indicated the price range in which they were tentatively interested, respondents were shown a drawing of that basic model;



they were then given a "standard sales talk" on each optional component, feature or design element, in much the manner an implement dealer would talk to them about it. Respondents leafed through the pictures in the folder as each such "extra" was explained, while the interviewer recorded their decisions feature-by-feature on a special score sheet made part of the questionnaire. Upon completing the presentation, this score sheet was handed to the respondent for detailed verification; "Was I correct in marking down that you preferred pneumatic tires?" et cetera, item by item.

The respondent was then invited to uncover a price column opposite each feature on the score sheet by removing a piece of masking tape which had concealed it. This column showed the amounts by which each item or "extra" had increased the price over that of the basic model he had originally set out to buy. Usually the respondent was surprised to see how the extras he had specified had increased the total price. As a final step he was asked to reconsider his choices of optional components and extras *in light of their impact on price* and arrive at a total price near what he wanted to pay.

Needless to say many prospective buyers, by indicating preferences for extras which increased the total price, "traded up", in effect moving to a higher price bracket than the one initially specified. The whole survey procedure was designed to reproduce a normal buying situation in actual sequence.

In this particular situation the survey enabled the manufacturer to reduce his product line from 30-odd models to three, effectively bracketing 89 percent of the market. When one of the country's largest buying organizations standardized on the models recommended in the survey, the manufacturer obtained substantial business that he might not have normally.

Mr. Barry states that this survey technique, although over-simplified in this brief discussion, has been widely applied to problems of designing products for both consumer and industrial use and for evaluating functional and aesthetic factors, particularly in combinations and in relationship to the price the buyer is willing to pay. Mr. Barry believes that it is especially desirable to follow such a procedure where tooling expenditures preparatory to volume manufacture are large. "It is worthwhile insurance," he said, "even where the cost of developing the final designs alone is substantial. This survey technique can not be employed by the amateur market researcher, but if utilized at the proper stage in product development, it can be worth many times its cost." END

STAFF COLUMNIST

MARTIN E. KAGAN
Martin E. Kagan is Vice President of Yardney Electric Corp.

CONVENTION NOTES:

Ideas for Your Design File

Engineering conventions seem to creep up on us at every turn and before we are finished reviewing one we are invited to another. With the phenomenal growth of these conventions it would be a true feat of miniaturization to report on any one of them in a single column. Despite its hundred technical sessions and close to four hundred conference papers the Winter Session of the AIEE that took place in New York this month will be fully reported in the heavy tomes of the transactions and periodicals of the largest engineering fraternity in the world. Here are merely a few notes on what caught the eye of one visiting engineer.

The AIEE picked out research, earth satellites and scientific education in Russia as some of the most pressing problems to be discussed at the convention. Other equally urgent problems, such as technological help for underdeveloped countries, might well have been identified for consideration. Some conference members were not unmindful of such problems, however. For example, it was reported, and it was encouraging to hear, that India is forging ahead in its technical education through its own efforts and the help of other nations and that it is looking ahead to a bright future with experiments in international graduate work at its University of Roorke.

It was also heartening to note that in contrast to previous years where power engineering held the stage almost singlehandedly, the scope of the conference had broadened to include missile electronics, engineering humanities and other diverse topics and that the Institute plans to make available translations of foreign scientific journals to its members. Of the many technical papers discussed, I would like to comment on two.

PROXIMITY SWITCHES

An interesting approach to the solution of a "difficult" and sometimes "impossible" problem in automation and control was presented by F. A. Manners and R. C. Mierendorf of the Square D Company.

In numerous recent applications conventional mechanical and photo-electric switches have not fulfilled their purpose adequately and reliably because of complex switching requirements of the newer applications. Now, however, many difficult problems can be handled by the use of a proximity switch as an input device.

The proximity switch comprises two circuit elements—the sensing element (or transducer) and the control means. The sensing element consists of two driving coils and a pickup coil, as shown in Fig. 1. Presence of magnetic

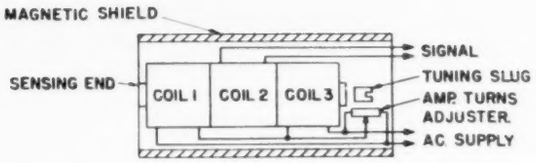


FIG. 1—The sensing element of the proximity switch consists of two driving coils and a pick-up coil. The undisturbed output signal may be preset with respect to amplitude and phase. The presence of magnetic material near the pick-up end causes a change in the phase and amplitude of the signal.

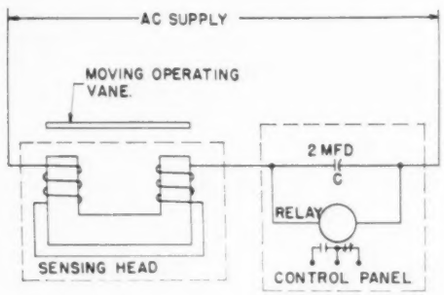


FIG. 2—Series resonant proximity limit switch. This detector includes a transducer mounted on the machine and a remotely mounted control panel. The transducer contains only an iron cored reactor. In one form of proximity detector, the control panel contains a relay, a capacitor and a reactor, and in another form, it contains only a relay and capacitor. These components are connected in a resonant circuit. When a vane of magnetic material moves into the field of the transducer reactor, the inductance changes, thereby changing the state of resonance of the circuit and causing the relay to pull in or drop out. One form of circuit is called the limit switch type, in which a relay is energized until the vane moves into the field of the transducer causing the relay to drop out, and the other is called the interlock type in which a relay is normally de-energized and picks up when the vane moves into the field of the transducer.

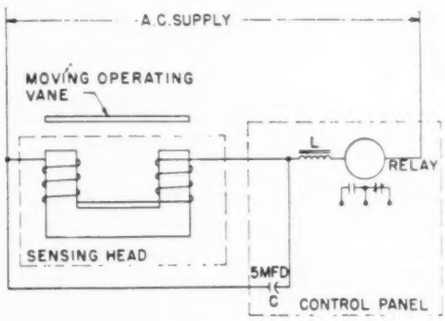


FIG. 3—Parallel resonant proximity interlock. In this circuit the transducer reactor is connected in parallel with a capacitor. In this parallel combination, the impedance of the capacitor is always less than that of the reactor so that the circuit represents a capacitive impedance. When the vane is close to the transducer, the inductance is high and its shunting effect on the capacitor is relatively small. When the vane is removed from the transducer, the inductance is reduced so that its shunting effect on the capacitor is increased and the parallel combination is equivalent to a smaller capacitor. The parallel combination of the transducer and capacitor is connected in series with a reactor L and a relay. If the vane is moved to within 1 inch of the transducer, the circuit approaches a series resonant condition between reactor L and the parallel circuit. This causes the relay current to increase and the relay picks up. As the vane is moved closer to the transducer, the relay current still tends to increase towards a resonant peak, but because of saturation of the core, the inductance of reactor L decreases, thus limiting the rise of relay current to a safe level.

material near the pickup end causes a change in phase and amplitude of the signal. The control panel receives the signal and amplifies it, conveying the signal to a phase-shift detector which converts the analogue change to a digital signal that can operate a relay or a converter to a static switch.

Interesting applications are given for such switches: inspection of cartons to insure presence of metallic parts, or conversely check of empty cartons to inspect for presence of parts before they are placed in an automatic loading machine. For steel mill applications design requirements of proximity devices are different. Size of transducer can be increased considerably with a corresponding decrease in complexity of control panel resulting in simple circuitry and ruggedness to match the application. Figures 2 and 3 describe two designs for such applications.

STATIC EXCITERS FOR AIRCRAFT A-C GENERATORS

In a paper by H. H. Briton and D. L. Plette of General Electric a simplification in the design of aircraft a-c generators through the use of a static exciter is described. Until recently most aircraft a-c generators in this country obtained their field excitation from a conventional d-c rotating exciter characterized by rotating windings and commutators to produce direct current. Slip rings carried excitation current to the rotating field of the a-c generator. In another type of rotating exciter used in recent years, the voltage, rectified by small rotating units, is supplied directly to the rotating field of the a-c generator.

The static or non-rotating type of exciter described by Briton and Plette extracts a portion of the voltage from the a-c generator to supply controlled excitation back into the field of the generator. Because the exciter is non-rotating it can be located in the most convenient place in the airplane from a wiring standpoint, an important consideration in aircraft generator design.

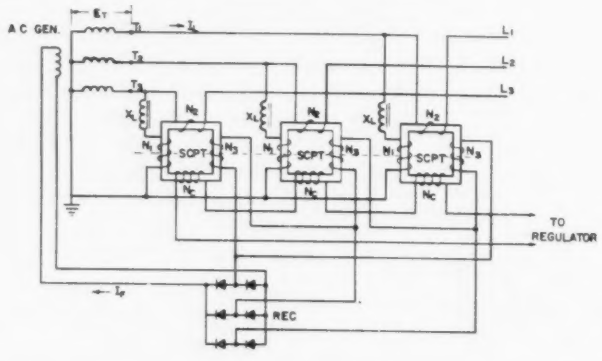


Fig 4—Symbolic representation of static exciter. It consists of three saturable current-potential transformers (SCPT), three reactors (X_L), and a three-phase full-wave rectifier. The SCPTs have three a-c windings and a d-c control winding. The a-c windings designated N_1, N_2, and N_3 are respectively the voltage, current, and output windings. The output windings are connected in delta. The SCPTs combining voltage and current quantities from the generator output in the correct proportion control the magnitude of the resultant field current in the generator by means of d-c saturation. The SCPTs also act as an impedance matching member between the generator output and the generator field. The reactors shift the phase of the current derived from the generator voltage with respect to that derived from load current such that the field current, which is proportianal to the vector sum of these currents, has self-corrective action with respect to changes in load and power factor. REC is the main field rectifier and converts the three-phase output of the exciter to d-c field excitation.

ADVERTISERS' INDEX

ADVERTISERS	Page Number	Inquiry Number
Airmatic Valve, Inc.	4	3
Atlas E-E Corp.	41	24
Avco Manufacturing Corp. Cover	2	1
Bird, Richard H., & Co.	6	4
Camin Laboratories, Inc.	39	21
Chemical Corp., The	43	25
Circle F Manufacturing Co. Cover	3	35
Consolidated Electrodynamics Corp.	2	2
Consolidated Electrodynamics Corp.	17	12
Continental Wire Corp.	61	34
Electro Switch Corp.	44	26
Electronic Assembly Co., Inc.	16	11
Fidelity Chemical Products Corp.	40	22
General Electric Co. (*Missile Guidance Product Section*)	59	33
Gibson Electric Co.	55	32
Grant Pulley & Hardware Corp.	19	13
Haydon, A. W., Co.	47	27
Howard Industries, Inc.	11	8
Interelectronics Corp.	49	30
International Resistance Co. (*Hycor Division*)	15	10
Ions Exchange & Chemical Corp.	31	18
Kulka Electric Corp.	55	31
Laboratory for Electronics, Inc.	22	15
Librascope, Inc. (*A Subsidiary of General Precision Equipment Corp.*)	7	6
Marion Electrical Instrument Co.	7	5
Mehlich, Peter, Organization	29	17
Joseph Pollack Corp.	10	7
Saginaw Bearing Co.	37	20
Southwest Products Co.	23	16
Southwest Products Co.	40	23
Staedtler, J. S. Inc.	48	29
Stonite Coil Corp.	36	19
United Electric Controls Co.	21	14
Wiegand, Edwin L., Co.	47	28
Yardney Electric Corp. Cover	4	36

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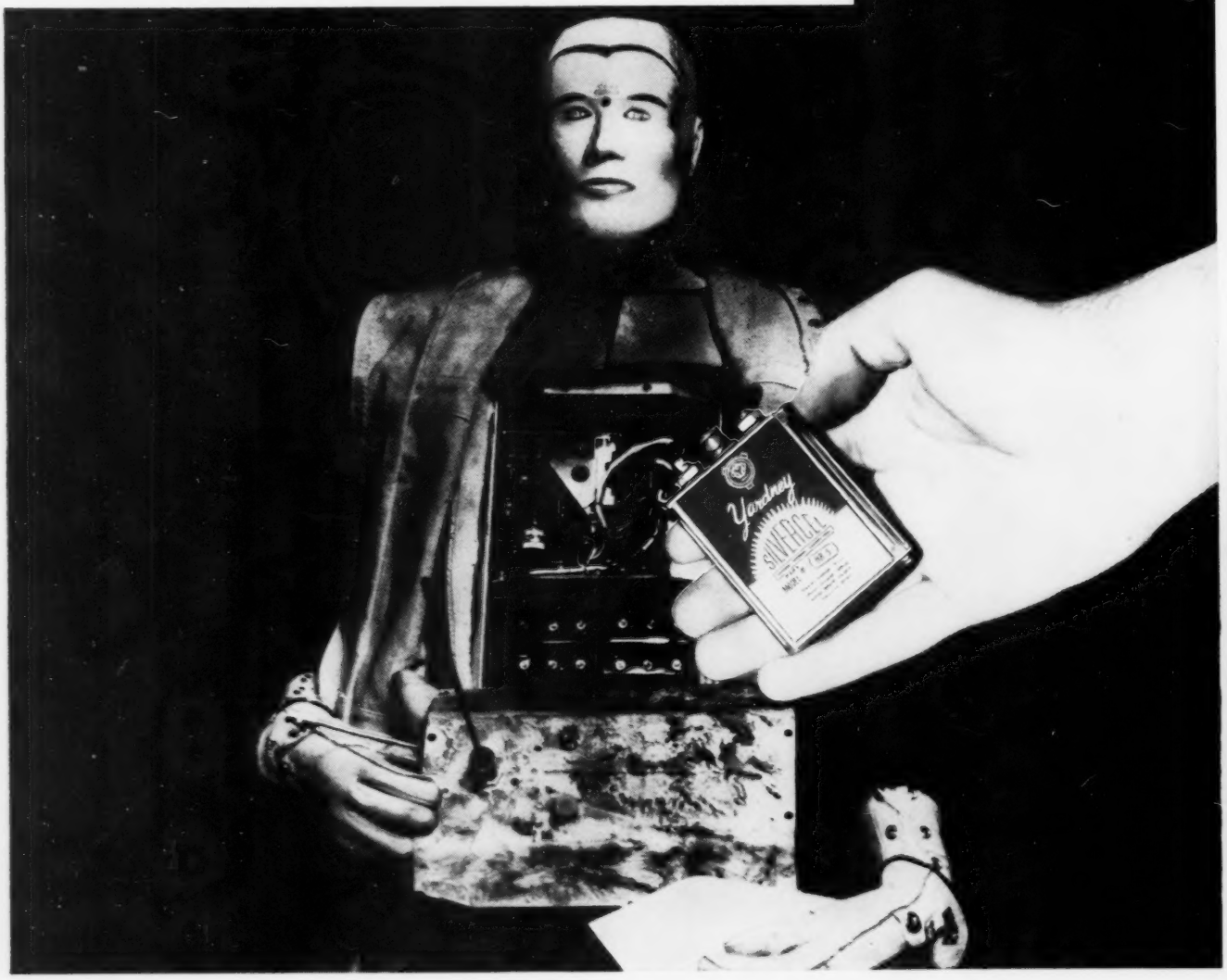

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